TE-81

INSTRUCTIONS
AND
PARTS BREAKDOWN

TRUE RMS ELECTRONIC VOLTMETER
MODEL 320-S/1

BALLANTINE LABORATORIES INC.

Prepared by
Western Electric Company
INCORPORATED
DEFENSE ACTIVITIES DIVISION
for UNITED STATES AIR FORCE

MP MASTER
MA34780

TE-81
September 1961

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TRUE ROOT MEAN SQUARE ELECTRONIC VOLTMETER
BALLANTINE MODEL 320-S/1

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TRUE ROOT MEAN SQUARE ELECTRONIC VOLTMETER
BALLANTINE MODEL 320-S/1

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TRUE ROOT MEAN SQUARE ELECTRONIC VOLTMETER
BALLANTINE MODEL 320-S/1

SECTION I
INTRODUCTION AND DESCRIPTION

1-1 PURPOSE AND USE

1-2 Ballantine Model 320-S/1 True Root Mean Square Electronic Voltmeter (Voltmeter) (figure 1-1) is an amplifier-detector type instrument primarily used for the measurement of a.-c. voltages. The meter scale indicates the root mean square (rms) value (effective value) of the applied a-c voltage. The meter indication of rms voltage is accurate not only for sine waves but for complex waves varying over a wide frequency range.

1-3 The voltmeter is useful for measuring a-c voltages in power, audio, and ultrasonic frequency ranges. Two voltage scales give a direct indication of rms voltage. In addition, a decibel scale permits the use of the voltmeter as a decibel meter. The indication obtained is in reference to 1 milliwatt of power in 600 ohms, i.e. dbm. This is particularly useful in measuring signal gain and loss in telephone equipment. However, the major use is in noise measurements where the true rms value of the noise is indicated.

1-4 The instrument is contained in a metal case with the panel meter and controls exposed (figure 1-1). It is essentially a high-impedance attenuator followed by a degeneratively stabilized amplifier which feeds a specially designed* square-law detector. This detector is characterized by a wide band response and is capable of maintaining the response under conditions of a wide dynamic voltage range. Further advantages are an instantaneous response and ability to operate without burning out.

1-5 Current from the detector is applied to a moving-coil meter. The voltage scales are logarithmic; however, the decibel scale is linear. The basic meter accuracy is maintained at any point on the meter scale. An auxiliary dial, marked in db decade steps and coupled to the range selector switch, supplements the meter db scale to facilitate db measurements over a wide range.

1-6 Incorporated in the instrument is a constant voltage source (Model 430 Calibration Unit). This plug-in unit applies a constant voltage to the meter when the calibrator is selected by a front-panel switch. This is used to check the calibration accuracy of the meter.

1-7. Additional functions may be performed by the voltmeter. A switch disconnects the detector from the amplifier and supplies a balanced-to-ground low-impedance output to a front-panel binding post. Another panel connector provides an amplified signal for monitoring with phones or oscilloscope. This can be performed while metering the voltage. A third panel connector leaves the detector operative but disconnects the meter and provides a mean-square output for recording devices.

*patent applied for

1-8 TECHNICAL CHARACTERISTICS

Voltage Range:	100 microvolts to 320 volts rms in 13 ranges; 130 decibels in 13 steps of 10 db each.
Frequency Range:	5 to 500,000 cycles per second (cps).
Crest-Factor Range (applies to a periodic wave with no d-c component and is the ratio of the peak amplitude to the rms amplitude):	1 to 5 for full-scale readings; 1 to 15.8 for bottom-scale readings.
Accuracy for Sine Waves:	3% from 15 to 15,000 cps; 5% from 5 to 15 cps; and 5% from 150,000 to 500,000 cps.
Accuracy for Non-sinusoidal Waves:	3% if all frequency components are within range of 15 to 150,000 cps; 5% for all other conditions within frequency and crest-factor ranges specified above.
Stability of Calibrating Source:	0.5% for line-voltage variations of 105 to 125 volts.
Input Impedance:	10 megohms, shunted by approximately 18 mmfd to 10-millivolt input signal; shunt capacitance is approximately 8 mmfd above 10 millivolts.
Meter Scales:	Logarithmic voltage scales reading in ranges from 1 to 3.2 and from 3.1 to 10. Linear decibel scale reading 0 to 10.
Output Characteristics:	MAIN-AMPLIFIER OUTPUT: (AMP OUT) available at three banana jacks mounted on front panel. Maximum voltage gain of 90 db ± 1 db bal-

1-8 TECHNICAL CHARACTERISTICS (cont)

Output Characteristics:

anced to ground, decreasing in 10 db steps to -30 db. Maximum undistorted output signal available at AMP OUT jacks is 25 volts.

MONITOR OUTPUT: available at telephone jack mounted on front panel. Maximum voltage gain of 84 db ± 1 db single ended, in phase with the input, decreasing in 10 db steps to -36 db.

MEAN SQUARE OUTPUT: available at telephone jack mounted on front panel. Negative d-c output voltage of 0.2v corresponding to full-scale meter deflection.

1-8 TECHNICAL CHARACTERISTICS (cont)

Power Supply:	105 to 125 volts or 210 to 250 volts, 50 to 420 cps, 65 watts.
Dimensions:	14-3/8 in. wide, 10-1/8 in. high, 12-3/8 in. deep.
Weight:	Voltmeter 21 pounds; packed for shipping, 40 pounds.

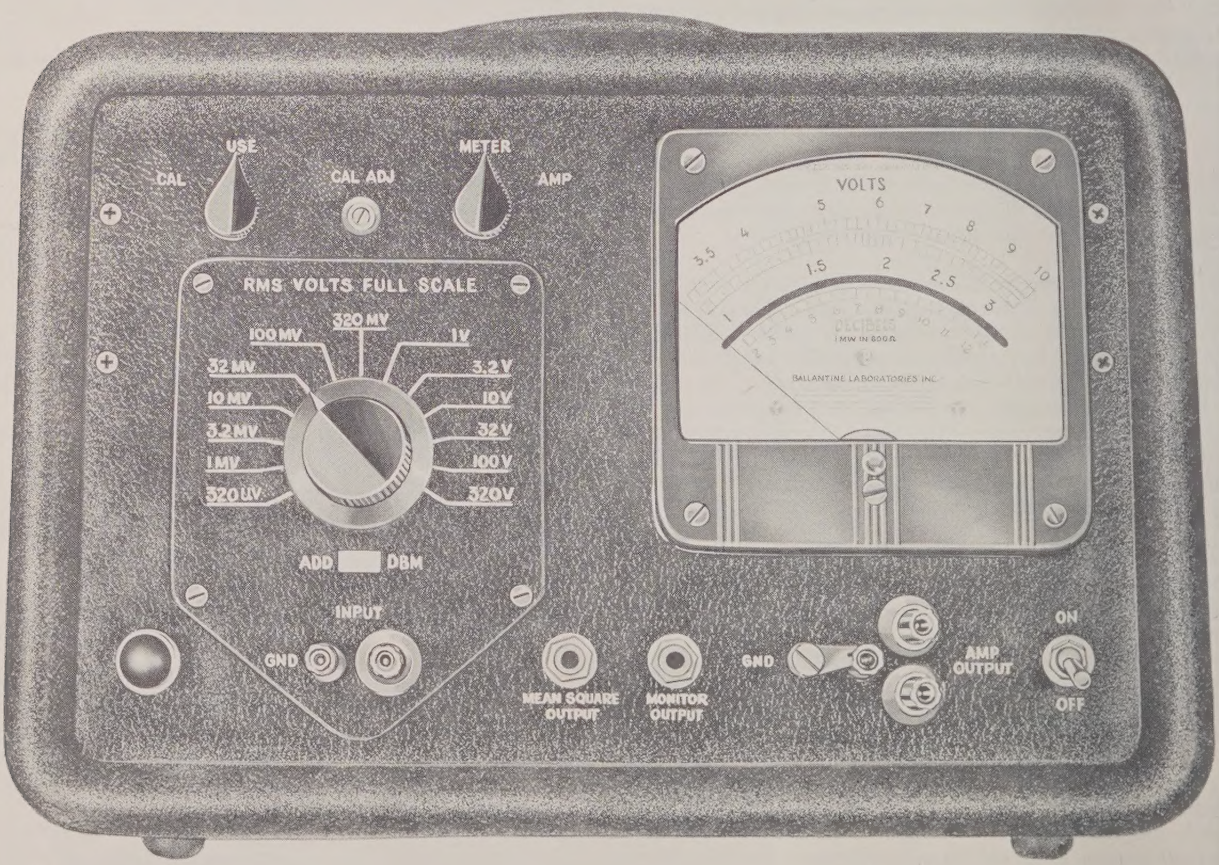


Figure 1-1. Ballantine Model 320 True Root Mean Square Electronic Voltmeter

TRUE ROOT MEAN SQUARE ELECTRONIC VOLTMETER
BALLANTINE MODEL 320-S/1

SECTION II
OPERATION

2-1 POWER CONNECTION

2-2 The voltmeter is supplied ready to operate on 105 to 125-volt, 40 to 420-cps power. A decal mounted adjacent to the power cord indicates this voltage. If necessary, the transformer connections can be changed to permit 210 to 250-volt operation (paragraph 4-14).

2-3 STARTING PROCEDURE

2-4 Insert two-prong power plug in a-c outlet; connect green lead from plug to power-system ground.

a. Place ON-OFF switch in ON position; red pilot light illuminates.

b. For initial turn-on or if equipment has been out of use for many months, permit a warm-up period of at least 30 minutes. In other cases, five minutes is sufficient.

--CAUTION--

Permit air to circulate freely at the rear of instrument. Be sure that no sources of heat are placed against back of instrument case.

c. Set METER-AMP switch at METER and do not change unless directed to do so in this handbook.

2-5 FUNCTION OF SWITCHES

2-6 There are a minimum of switches required for operation of the voltmeter. The function of each is explained in table I.

2-7 RANGE SELECTION

--WARNING--

The RANGE SELECTOR switch should always be in extreme clockwise position before connecting voltage to input terminal, and should always be returned to that position before removing the voltage. This reduces possibility of damage due to overload or transient surges.

2-8 VOLTAGE READING

2-9 Select voltage range with an RMS VOLTS FULL SCALE deflection greater than anticipated voltage to be measured.

--NOTE--

If voltage to be measured is unknown, start with switch at maximum rms volts full scale position.

2-10 Apply voltage to be measured to INPUT (see paragraph 2-21).

TABLE I. FUNCTION OF SWITCHES

TITLE	POSITION	FUNCTION
ON-OFF	ON	Applies a-c power to instrument.
	OFF	Removes power.
USE-CAL	USE	Applies portion of voltage being measured to first amplifier tube.
	CAL	Applies 3.162 millivolts to first amplifier tube as a calibrating voltage.
Range Selector		Sets instrument to read one of 13 positions of RMS VOLTS FULL SCALE, as indicated on front panel.
METER-AMP	METER	Applies amplifier output to metering circuit.
	AMP	Delivers amplifier output to AMP OUT jack on front panel.

2-11 Read VOLTS scale.

--NOTE--

Scale to read and multiplying factor to apply is indicated by setting of RMS volts full scale switch setting.

2-12 DECIBEL READING

2-13 If decibel reading is required instead of voltage reading, proceed as for a voltage reading but read the DECIBELS scale of the meter.

2-14 Obtain actual db reading by adding the meter indication to the red number appearing in aperture below range switch knob. The result is the decibel indication in dbm, i.e. decibels with a reference of 1 milliwatt of power in an impedance of 600 ohms.

2-15 USE OF CALIBRATOR

2-16 The calibrator need not be used constantly. It should be used if the instrument is returned to use after having been out of service for several months, during periodic maintenance, and when repairs have been performed on the instrument.

2-17 The procedure is given on the meter face but is summarized here.

a. Set range selector switch to either 3.2MV, 100MV, 3.2V, or 100V FULL SCALE.

b. Switch USE-CAL switch to CAL and adjust CAL ADJ control until meter reads exactly 10 on the 3.1 to 10-volt scale.

c. Set range selector switch to next higher range (clockwise rotation) and adjust meter screw for a meter reading of exactly 1 volt.

d. With the USE-CAL switch on CAL, repeat steps 2-17 a through c until no further adjustments are necessary.

e. Set switch to USE position and leave until instructed to change or until another calibration check is required.

--NOTE--

Although the amplifier calibrating voltage is available at AMP OUT and MONITOR OUT connectors, the accuracy is not as close as the accuracy of the calibrating source. This is due to variations in amplifier performance. The mean square output with the calibrator in use is accurate to within 4%.

2-18 USE OF METER SCREW

2-19 If more convenient operation or greater accuracy than is given with the calibration procedure in paragraphs 2-15 through 2-17 is desired, the meter-screw adjustment may be performed.

2-20 Proceed as follows:

a. Set USE-CAL switch to USE.

b. Apply a signal to INPUT that gives a reading of exactly 10 on 3.1 to 10-volt scale.

--NOTE--

In the following step, do not attempt to obtain reading if no signal is applied to the input terminals

c. Change range selector switch to next higher db range (clockwise rotation). Reading of exactly 1 volt should be obtained. It may vary by 0.2 decibels (indicated on the DECIBEL scale) but should approach this figure only with high-crest-factor input signals.

d. Adjust meter screw to give precise overlap.

--NOTE--

Do not use CAL ADJ control for this asjustment.

2-21 RMS VOLTAGE MEASUREMENT

--NOTE--

The test lead used depends upon the signal being measured. However, for general use, a short length of low-loss, low-capacitance cable is recommended. A shielded telephone plug should be on the instrument end; alligator clips on the test-voltage end.

2-22 To measure rms voltage, proceed as follows:

a. Set range selector switch (paragraph 2-7).

b. Connect voltage to be measured to INPUT through test leads.

--WARNING--

Left terminal "G" is grounded to instrument case. If voltages above ground (either AC or DC) are measured, a shock hazard exists. Exercise caution.

c. Read voltage indication on proper VOLTS scale; and multiply by the factor to be used for the range selected.

2-23 MEASUREMENT OF NOISE AND OTHER NONSINUSOIDAL VOLTAGES

2-24 Measurement of Noise

2-25 The instrument reading of rms voltages with a crest factor (peak factor) of less than 5 is accurate within the same limits as a sine-wave voltage reading. Since the crest factor of random noise, either narrow or wide band, does not, for all practical pur-

poses, exceed 5, the true rms value of a random-noise signal is directly indicated by the instrument. This is true if the noise frequencies lie entirely within the frequency range of 15 to 150,000 cps. (The maximum instrument error is then ± 3% for all the instrument voltage ranges.) The error reaches ± 5% if any of the frequency components lie below 15 cps or above 150,000 cps, that is, those signals which lie entirely within the band of 5 to 500,000 cps. Should any of the frequency components of the voltage being measured extend beyond 500,000 cps, a larger error is incurred. However, if the noise frequencies are restricted to approximately 1,000,000 cps maximum, the error remains relatively small.

2-26 Measurement of Non-Sinusoidal Voltages With Crest Factors of 4 of Less.

2-27 If the crest factor of the non-sinusoidal wave being measured is less than 5, the instrument reading is accurate within the limits that apply to a sine wave. The same considerations apply to these low-crest factor non-sinusoidal voltages as to noise voltage.

2-28 Measurement of Non-Sinusoidal Voltages With Crest Factors Between 5 and 15.8

2-29 The limit of linear and accurate response of the amplifiers and square-law detector occurs at a peak voltage five times the rms voltage corresponding to full-scale meter deflection. Therefore, should the crest factor of a signal be greater than 5 (but less than 15.8) it is required that the rms value of the signal be less, or be attenuated to be less, than a full-scale reading.

2-30 The maximum permissible fraction of full-scale volts is obtained by dividing 5 by the crest factor of the voltage to be measured. Thus, a signal with a crest factor of 10, for example, can be measured correctly only if it is attenuated by networks external to the instrument to give a reading no higher than 1/2 of full scale, i.e. 1.58 on the 1 to 3.2 VOLTS scale or 5 on the 3.1 to 10 VOLTS scale. The amount of such attenuation must be exactly known if the rms voltage is to be accurately determined. Within this restriction, the maximum instrument errors are the same as for non-sinusoidal waves with crest factors of 5 or less. To minimize errors, adjust meter screw in accordance with procedure of paragraphs 2-18 through 2-20.

2-31 EFFECTS OF FREQUENCY COMPONENTS NOT WITHIN INSTRUMENT BAND WIDTH

2-32 In the case of signals containing frequency components outside the 5 to 500,000 cps limits of the instrument, an error is introduced. In practical measurements, the error is not excessive because the instrument frequency response falls off gradually outside the specified frequency limits, i.e. frequencies above 500,000 cps are attenuated but not actually eliminated.

2-33 AC OVERLOAD CHARACTERISTICS

2-34 The maximum a.-c. signal voltage overload which may be applied to the instrument is determined by damage likely to occur to the input attenuator and first amplifier tube. For ranges to 10MV FULL SCALE, 1-volt rms may be applied continuously to the input without damage. For the next three ranges (to 320MV FULL SCALE) 32-volts rms may be safely applied. For the remainder of the ranges (to 320MV FULL SCALE) the limit is 1,000-volts rms or 1,600-volts peak. Voltage in excess of these limits do not necessarily damage the instrument, particularly if the overload is quickly removed. However, after the instrument has been subjected to an overload, the calibration should be checked in accordance with the procedure of paragraphs 2-15 through 2-17. The meter itself is protected against damage due to ac-signal overloads, unless a severe overload is periodically repeated and continued over a long time.

2-35 DC COMPONENT OF INPUT SIGNAL

2-36 The rms voltage measured by the instrument does not include the effect of any d.-c. component in the input signal. If the dc component is independently measured, the complete rms value may be calculated as follows:

$$E_{\text{rms complete}} = \left(E_{\text{dc}}^2 + E_{\text{rms ac}}^2 \right)^{\frac{1}{2}}$$

The maximum d.-c. voltage which may be applied to the INPUT is 1,000 volts. If a dc voltage is in excess of 1,000 volts, an external blocking capacitor must be used in series with the INPUT connector. Use a capacitor with a large leakage resistance, such as a plastic-film capacitor.

2-37 EXTENDING USEFULNESS OF INSTRUMENT

2-38 Accessories, which are not supplied, permit the instrument to measure rms voltages below 100 microvolts or above 320 volts. These are Ballantine Model 220A Decade Amplifier for the former and Model 1320 Multiplier and Model 620 Extra-High-Voltage Multiplier for the latter.

2-39 RMS CURRENT MEASUREMENTS

2-40 The instrument may be used to measure currents indirectly from 0.1 microampere to 10 amperes. This necessitates the use of accurate external resistors. To read current within the same limits of frequency and crest factor as apply to voltage measurements, proceed as follows:

a. Connect a precision resistor of 0.01, 0.1, 1.0, 100, or 1,000 ohms across the INPUT terminals of the instrument. The value used depends upon the current and the resulting voltage.

b. Read rms voltage as described in paragraph 2-21.

c. Divide voltage by the value of resistance connected across the INPUT terminals to obtain current in amperes.

--NOTE--

Current measurements are preferably made at points adjacent to ground.

2-41 POWER-DISSIPATION MEASUREMENTS

2-42 Measurement of true a.-c. power dissipation is possible with the instrument. The possible range of power measurements is 130 db, which for 600 ohms corresponds to the range from 16.7 micromicrowatts to 167 watts, or -77.8 dbm to +52.2 dbm. The power can be determined in terms of rms voltage or may be in decibels. By using the DECIBELS scale of the meter in conjunction with the db range switch indicator, a direct power reading is attainable. To obtain power dissipation readings in terms of rms voltage, proceed as follows:

a. Connect a precision resistor of known value across INPUT terminals.

b. Measure voltage across resistor.

c. Calculate power dissipation by use of formula,

$$P = \frac{E^2_{rms}}{R_{load}}$$

2-43 USE OF MAIN-AMPLIFIER OUTPUT

2-44 The instrument provides a wide-band high-gain amplifier for external use, if required. An output balanced to ground is available. To use the output, do the following:

a. Set METER-AMP switch to AMP.

b. Connect leads from red AMP OUT terminals to external device; connect a.-c. ground to black AMP OUT terminal.

c. Connect shorting link between black AMP OUT terminal and GND unless it is desired to elevate output to some d.-c. level. If this is required, proceed to paragraph 2-45.

2-45 Should it be desired to elevate the balanced output circuit to some d.-c. potential (as when the instrument is used as a preamplifier for a balanced power-output device), do the following:

a. Remove shorting link between black AMP OUT terminal and GND.

b. Apply d.-c. potential to black AMP OUT terminal.

--NOTE--

Do not exceed +300 or -100 volts dc.

2-46 USE OF MONITOR OUTPUT

2-47 The output is a signal in phase with the signal applied to the INPUT. To obtain the signal for visual or audible monitoring, insert a phone plug and cord in the MONITOR OUT jack.

--NOTE--

Although the MONITOR OUT is independent of the metering function, systems connected to the MONITOR OUT jack should be shielded from the source being measured (or vice versa). This is particularly important when low-level or high-frequency signals are present.

2-48 USE OF MEAN-SQUARE OUTPUT

2-49 To use the MEAN SQUARE OUT, proceed as follows:

a. Set METER-AMP switch to METER position.

b. Connect telephone plug and cord to MEAN SQUARE OUT jack.

c. Connect other end of cord to device to be driven, for example, Esterline-Angus recorder. (See paragraphs 3-24 through 3-27 for theory of MEAN SQUARE OUT.)

2-50 CHANGING RESPONSE TIME

2-51 The response time of the MEAN SQUARE OUT is approximately 0.25 seconds. During this time, the output reaches 90% of its final amplitude. It is possible to change this response time by altering the equipment.

--NOTE--

Do not make changes unless authorized by higher authority.

2-52 To reduce response time, remove capacitor C27 and replace with a capacitor of lower value. The low-frequency response of the instrument will be raised in proportion to the ratio of old to new capacitance value.

2-53 An alternate method used to reduce response time is the shunting of resistor R55. This method reduces the output voltage of the instrument.

2-54 To increase response time, add a tantalum capacitor with a minimum voltage rating of six volts to capacitor C27.

2-55 USING CURRENT-SENSITIVE LOAD ON MEAN-SQUARE OUT

2-56 To use a current-sensitive device as a load (resistance of 1,000 ohms or less), remove resistor R55. The d.-c. output current corresponding to full-scale meter deflection is -200 microamperes. However, with the alteration, currents up to -4 milliamperes may be drawn. As a precaution to obtain accurate indications, the load resistance must be decreased so that the load voltage does not exceed -0.2 volts. An external meter may be used in some remote location or a meter with a special scale calibration may be used instead of the meter in the instrument.

--CAUTION--

When connecting MEAN SQUARE OUT jack to an external source with dc present, the dc must be disconnected when inserting and removing plug to prevent permanent damage to the meter.

TRUE ROOT MEAN SQUARE ELECTRONIC VOLTMETER
BALLANTINE MODEL 320-S/1

SECTION III
THEORY

3-1 BLOCK-DIAGRAM DISCUSSION

3-2 INPUT ATTENUATOR

3-3 The overall theory of operation of the Ballantine Model 320-S/1 True Root Mean Square Electronic Voltmeter is illustrated in the block diagram, figure 3-1. The rms voltage to be measured is applied through INPUT jack to the input attenuator. This attenuator presents a very light load to the input signal (10 megohms). The attenuator is capacity compensated, permitting operation over a wide frequency range. In addition, the attenuator limits the input voltage to a value that prevents overloading the electron-tube amplifiers. The attenuation factors for the positions of the range switch are 1, $10^{\frac{3}{2}}$, 10^{3}, and $10^{\frac{9}{2}}$ for positions 320uv to 10mv, 32mv to 320 mv, 1v to 10v, and 32v to 320v full scale, respectively. The signal experiences further attenuation in the midsection attenuator, after being amplified. Table II summarizes the result of operation of the combined attenuators on the applied voltage.

3-4 AMPLIFIER A

3-5 Amplifier A consists of three resistance-capacitance (rc) coupled pentode amplifiers (V1 through V3) operating in a wide-band high-gain circuit. Even though 40db feedback is employed, the overall gain is 52db. The first amplifier tube contributes gain with low noise, minimum hum, and lack of microphonics. The use of d.-c. on the heaters of the first two stages (V1 and V2) is responsible for the low hum level.

3-6 MIDSECTION ATTENUATOR

3-7 Attenuation ratios of 1, $10^{\frac{1}{2}}$, 10, and $10^{\frac{3}{2}}$ are obtained in the midsection attenuator, a resistive voltage divider incorporating no frequency compensation. The midsection attenuator is controlled by a section of the range selector switch, which also controls the input attenuator. Thus, changes of input-attenuator and midsection-attenuator positions take place simultaneously. The combined effect of both attenuators is shown in Table II.

3-8 AMPLIFIER B AND OUTPUT CATHODE FOLLOWER

3-9 Two pentode-triode-type tubes (V4 and V5) are used as the output amplifier and phase inverter. The two triode sections operate as cathode followers to drive the output transformer in push-pull; the push-pull circuitry allows full rectification of the input signal. A gain of 32db is obtained in amplifier B, which incorporates the same amount of feedback as amplifier A. The feedback minimizes distortion and reduces the effects on circuit gain of a change in tubes or in deterioration in tube characteristics. In addi-

TABLE II. ATTENUATION APPLIED TO VOLTAGE INPUT

RANGE SWITCH FULL SCALE (Volts, unless otherwise specified)	INPUT ATTENUATOR RATIO	MIDSECTION ATTENUATOR RATIO	TOTAL ATTENUATION RATIO
320uv	1	1	1
1mv	1	$10^{\frac{1}{2}}$	$10^{\frac{1}{2}}$
3.2mv	1	10	10
10mv	1	$10^{\frac{3}{2}}$	$10^{\frac{3}{2}}$
32mv	$10^{\frac{3}{2}}$	$10^{\frac{1}{2}}$	10^{2}

TABLE II. ATTENUATION APPLIED TO VOLTAGE INPUT (cont)

RANGE SWITCH FULL SCALE (Volts, unless otherwise specified)	INPUT ATTENUATOR RATIO	MIDSECTION ATTENUATOR RATIO	TOTAL ATTENUATION RATIO
100mv	$10^{\frac{3}{2}}$	10	$10^{\frac{5}{2}}$
320mv	$10^{\frac{3}{2}}$	$10^{\frac{3}{2}}$	10^{3}
1	10^{3}	$10^{\frac{1}{2}}$	$10^{\frac{7}{2}}$
3.2	10^{3}	10	10^{4}
10	10^{3}	$10^{\frac{3}{2}}$	$10^{\frac{9}{2}}$
32	$10^{\frac{9}{2}}$	$10^{\frac{1}{2}}$	10^{5}
100	$10^{\frac{9}{2}}$	10	$10^{\frac{11}{2}}$
320	$10^{\frac{9}{2}}$	$10^{\frac{3}{2}}$	10^{6}

tion, gain remains more constant with line-voltage variations.

3-10 DETECTOR AND METER

3-11 For true rms indication of voltage, a square-law device is required, i.e., a detector with a current response that varies as the square of the input voltage. For example, the current flow quadruples if the input voltage to the square-law device is doubled. Various devices exhibit this characteristic but are accompanied by many disadvantages. However, a square-law characteristic can be simulated by using linear resistors in combination with voltage-biased diodes. If many sections of resistors and diodes are combined, the parabolic characteristic of a square-law device is obtained. The voltmeter employs this type of detector utilizing high-back-resistance germanium diodes in a unique circuit designed to minimize the effects of crystal imperfection. Nine linear segments are used, yielding a controlled squaring error of less than one percent over most of the 50 dynamic range of input voltage (2,500 to 1 current range).

3-12 In addition to the segments described in paragraph 3-11, a full-wave rectifier using crystal diodes is used to produce positive voltage signals from the secondary of the output transformer. The resultant current is proportional to the square of the input voltage. This current is read on the 200-microampere meter. The meter is calibrated in terms proportional to the square root of its current; consequently the root-mean-squaring operation is accomplished.

3-13 CALIBRATOR UNIT

3-14 A Model 430 Calibrator Unit is supplied with the voltmeter as a plug-in unit. The calibration of the meter can be checked for accuracy against the output of the calibrator. The calibrator may also be used as a separate calibration standard for external use. The calibrator is a constant-voltage source utilizing passive circuit elements. When an input voltage between 5.75 and 6.85-volts rms, 50 to 420 cps, is applied, an output of 3.162mv rms ± 0.5% is delivered to the input of the voltmeter when the USE-CAL switch is placed in the CAL position. The heater voltage of the voltmeter is used as the input source. The heater voltage will remain within the permissible tolerance limits if the line-voltage variations are between 105 and 125 volts.

3-15 The calibrator is a complete unit which may be removed from the instrument without disabling its other functions.

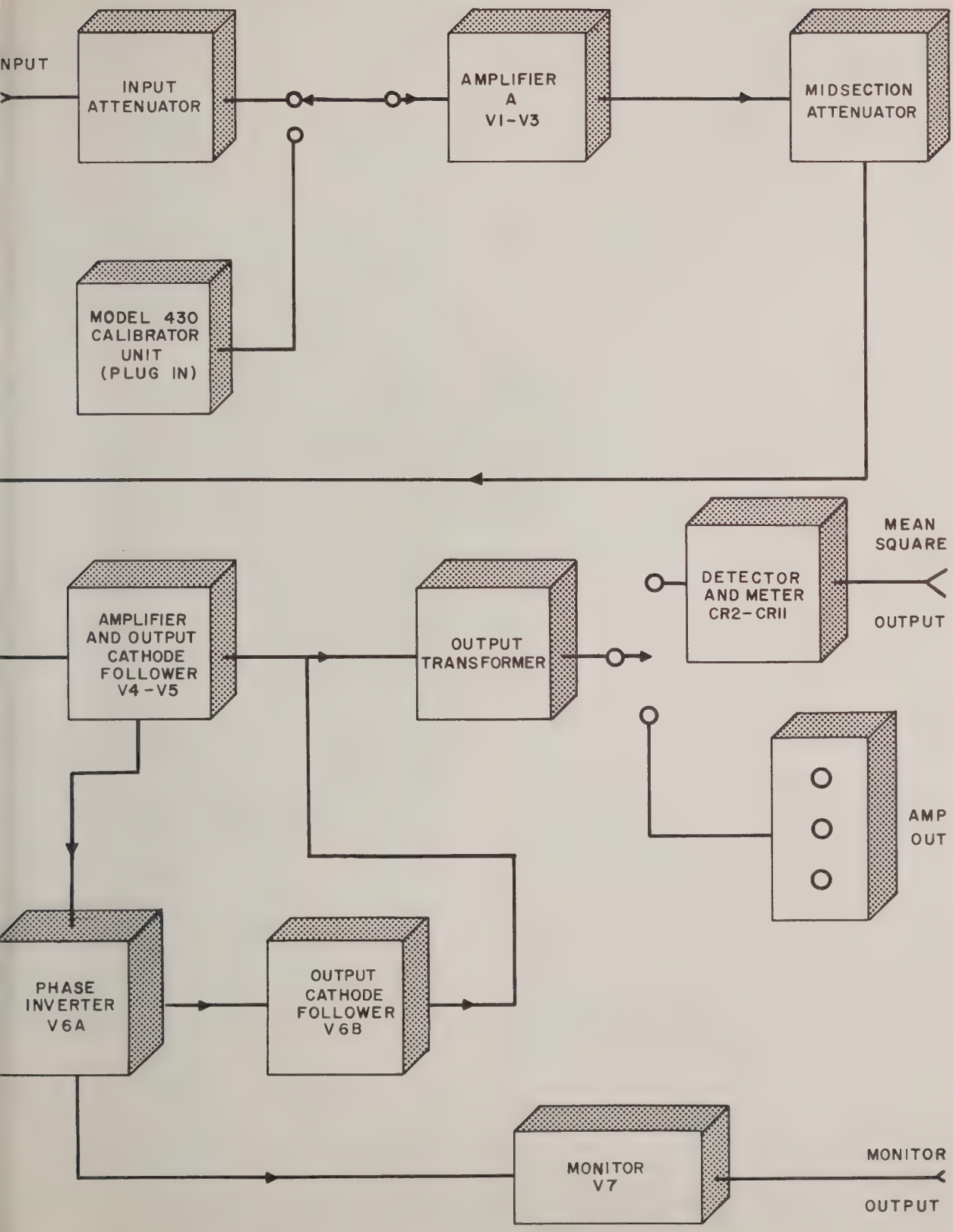


Figure 3-1. Ballantine Model 320-S/1 True Root Mean Square Electronic Voltmeter, Block Diagram

3-16 AUXILIARY FUNCTIONS

3-17 Monitor Output

3-18 An output is obtained from the phase inverter and is made available at the front-panel MONITOR OUT jack. The signal obtained is in phase with the voltmeter input and may be used for visual monitoring on an oscilloscope, or may be audibly monitored on a headset or external amplifier and speaker. The metering function is undisturbed when monitoring. The signal is approximately 5-volts rms when the meter is indicating full scale. Thus, with a range-selector-switch setting of 320uv FULL SCALE, the voltage gain from the INPUT jack to the MONITOR OUT is 84db ± 1db, from 5 to 500,000 cps. Each successive position of the range selector switch reduces the gain by 10db, down to -36db.

3-19 Main Amplifier Output

3-20 With the METER-AMP switch in the AMP position, the square-law detector and meter are disconnected from the instrument and the balanced-to-ground output signal from the output transformer is connected to the red AMP OUT terminals. A-c ground is connected to the black AMP OUT terminal. A shorting link permits connecting the a-c ground terminal to d-c ground if desired. The balanced output voltage corresponding to a full-scale meter deflection is approximately 10-volts rms. Thus, with the range selector switch at 320uv FULL SCALE, the voltage gain from the INPUT jack to the AMP OUT terminals is 90db ± 1db, from 5 to 500,000 cps. Each successive position of the range selector switch reduces this gain by 10db, down to -30db.

3-21 The a.-c.-source impedance for the balanced output is approximately 350 ohms. (This figure is only a rough approximation.) The d.-c. output resistance is 150 ohms.

3-22 The output circuit is balanced to ground; but under some conditions it may be desirable to use the output balanced at some d.c. reference potential. In such cases, remove the shorting link between the black AMP OUT terminal and GND. Connect the dc reference potential to the black AMP OUT terminal.

--CAUTION--

Do not use dc voltages in excess of +300 or -100.

3-23 For single-ended output, either red AMP OUT terminal may be grounded. However, this is not recommended where wide-band operation is required.

3-24 Mean-Square Output

3-25 With the METER-AMP switch in the METER position, an output can be obtained from the MEAN SQUARE OUTPUT jack. Inserting a telephone plug disconnects the meter from the detector circuit and substitutes a resistor as a load. The output is a negative voltage that is proportional to the mean square of the signal applied to the INPUT jack. The voltage output, corresponding to a full-scale meter deflection is -0.2 volts, and 0.02 volts corresponding to bottom-scale deflection. This permits a crest factor of 5. The d-c output can be increased to 5-volts maximum but at the expense of decreased crest-factor margin and reduced accuracy.

3-26 The voltage obtained from the MEAN SQUARE OUTPUT jack may be recorded, with time or frequency as the independent variable, using an Esterline-Angus pen recorder.

3-27 The response time of the mean-square output is approximately 0.25 seconds. In this time, the output reaches 90% of its final amplitude. This time may be changed, if desired, in accordance with the procedure of paragraphs 2-49 through 2-53.

3-28 DETAILED CIRCUIT ANALYSIS

3-29 INPUT ATTENUATOR

3-30 The voltage to the input-voltage amplifier is limited to permit linear operation of the tube. Since the input voltages may vary over a range of 1,000,000 to 1, the attenuator prevents overloading. In addition, a high input resistance prevents the instrument from loading the source being measured.

3-31 When measuring voltages on the four lowest ranges (10mv maximum), a direct input is used (figure 3-2). Capacitor C1 is in series with the input to block d.c. from the circuit. The voltage applied to the INPUT terminals is applied through S1A, S1B, and the USE position of the USE-CAL switch to resistors R5A and R5B. The voltage across these series-connected resistors constitutes the input to the first amplifier tube.

3-32 On the next three voltage ranges (32mv to 320mv full-scale deflection), the INPUT voltage is connected through series resistor R1 (shunted by capacitors C3A and C3B) to resistor R2 (shunted by capacitors C2A and C2B). The voltage across R2 is also across resistors R5A and R5B, which are in parallel with R2. Consequently, the input voltage is divided, with the major part of the voltage dropped across resistor R1. Thus, the input to the amplifier is maintained below the voltage that would overload the tube. The capacitive voltage divider consisting of C3 and C2 is also connected across the INPUT. Adjustment of the capacitance in each section of the divider is provided by trimmer capacitors (C2A and C3A). The procedure for adjusting these capacitors is explained in paragraphs 4-33 through 4-38. For the other range-switch positions, resistive voltage dividers limit the input voltage and capacitors are used to maintain the accuracy over a wide frequency range.

3-33 CALIBRATION UNIT

3-34 The calibration unit is a plug-in assembly which produces a constant output voltage and consists solely of passive circuit elements connected in a bridge circuit. The bridge is driven by the center-tapped secondary of a transformer. The heater voltage is applied to the primary. An additional secondary winding

is used and is connected in the circuit to buck out changes in voltage. This aids in maintaining the constant voltage output.

3-35 The second factor in stabilizing the voltage output of the calibrator is resistance lamp RT101. The resistance lamp is one arm of the bridge, the other arms consisting of the two windings of the center-tapped secondary of the transformer (S1 and S2) and resistor R101B. Since the resistance lamp, prior to heating, has a lower ohmic resistance than R101B, the bridge is not balanced. Consequently, some output is obtained across resistor R101A. Secondary S3 of transformer T101 is connected in opposition to the voltage applied to the bridge, and the voltage drop across resistor R105 produces an output of slightly more than 1 volt across voltage-divider resistors R103, R104A and R104B. Resistor R103 is adjusted for exactly 1 volt at PIN 5 of the output socket. The divider sets a voltage of 3.162 millivolts at PIN 6.

3-36 The complete operation of the calibrator is most easily understood by considering the action of resistance lamp RT101 in the bridge circuit. If the input voltage to the bridge rises, the current flow through the resistance lamp increases. The heating effect causes the resistance of the lamp to rise. Since the lamp represents a lower resistance than resistor R101B initially, the increase in resistance of the lamp reduces the ohmic difference between lamp and resistor. Further voltage increases the lamp resistance. At one point the resistances will be equal. Further increases in transformer voltage beyond this point causes the lamp's resistance to become higher than the resistance of resistor R101B. Since the S1-S2 transformer-winding impedance relationships do not change, the bridge output is dependent upon the relationship between the resistance lamp and the fixed resistor R101B. The bridge output changes in a linear relationship through one portion of the curve. It is within this range of input-voltage variations that the calibrator maintains a constant output voltage. Since the voltage changes in secondary winding S3 is in direct relationship with the change of primary voltage, and since the S3 voltage is in opposition to the bridge output voltage, the net result is a stable output within limits of input voltage.

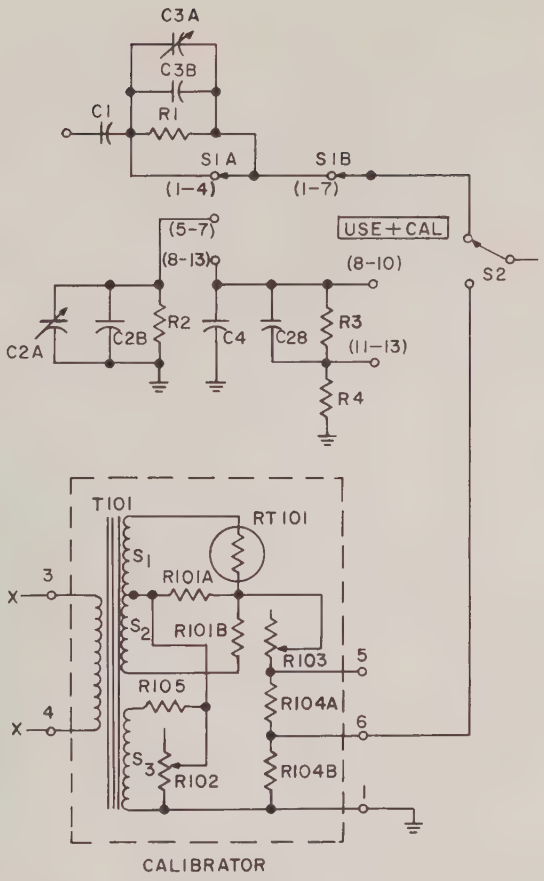


Figure 3-2. Input Attenuator and Calibration Unit, Schematic Diagram

3-37 AMPLIFIER A

3-38 Amplifier A (figure 3-3) consists of three rc-coupled pentode amplifier stages incorporating inverse feedback from the third stage. All stages use the same tube, type 5654, in similar circuits. The final stage differs in the use of a peaking arrangement to improve the response at high frequencies.

3-39 INPUT AMPLIFIER

3-40 Input amplifier V1 is rc coupled from the input attenuator and operates as a class A voltage amplifier. Bias is obtained from cathode bias resistor R9, which is bypassed by capacitor C29. This maintains a steady bias voltage. Although resistor R10 also contributes some small bias, the voltage across resistor R10 varies in accordance with the plate-current variations of both V1 and V3 since this resistor is common to both stages. The voltage developed is degenerative to the input and tends to increase the linearity of amplifier stages V1 through V3. In addition, the effects of changes in the electron tubes on amplifier gain is reduced. The output voltage of V1 is developed across plate load resistor R8. The plate voltage for this stage is supplied from the 255-volt regulated power supply. Since considerable gain follows this stage, the supply voltage is filtered additionally by capacitors C30 and C6A and resistors R76 and R12. These components serve the additional function of decoupling the plate and screen circuits of V1 from the power supply. As a further aid in reducing hum and noise in the input amplifier, the heaters of V1 and V2 are powered by d.c. obtained from a separate rectifier in the power supply. Parasitic suppression is provided in the control-grid circuit by resistor R6 and in the screen-grid circuit by resistor R11. The output of V1 is coupled to the second amplifier stage through capacitor C8.

3-41 Second Amplifier Stage

3-42 The second amplifier stage is also a class A amplifier. Cathode-resistor bias is obtained from resistor R15, which is unbypassed. This introduces local feedback within the amplifier stage. The plate load resistor is R14 and the plate voltage is filtered

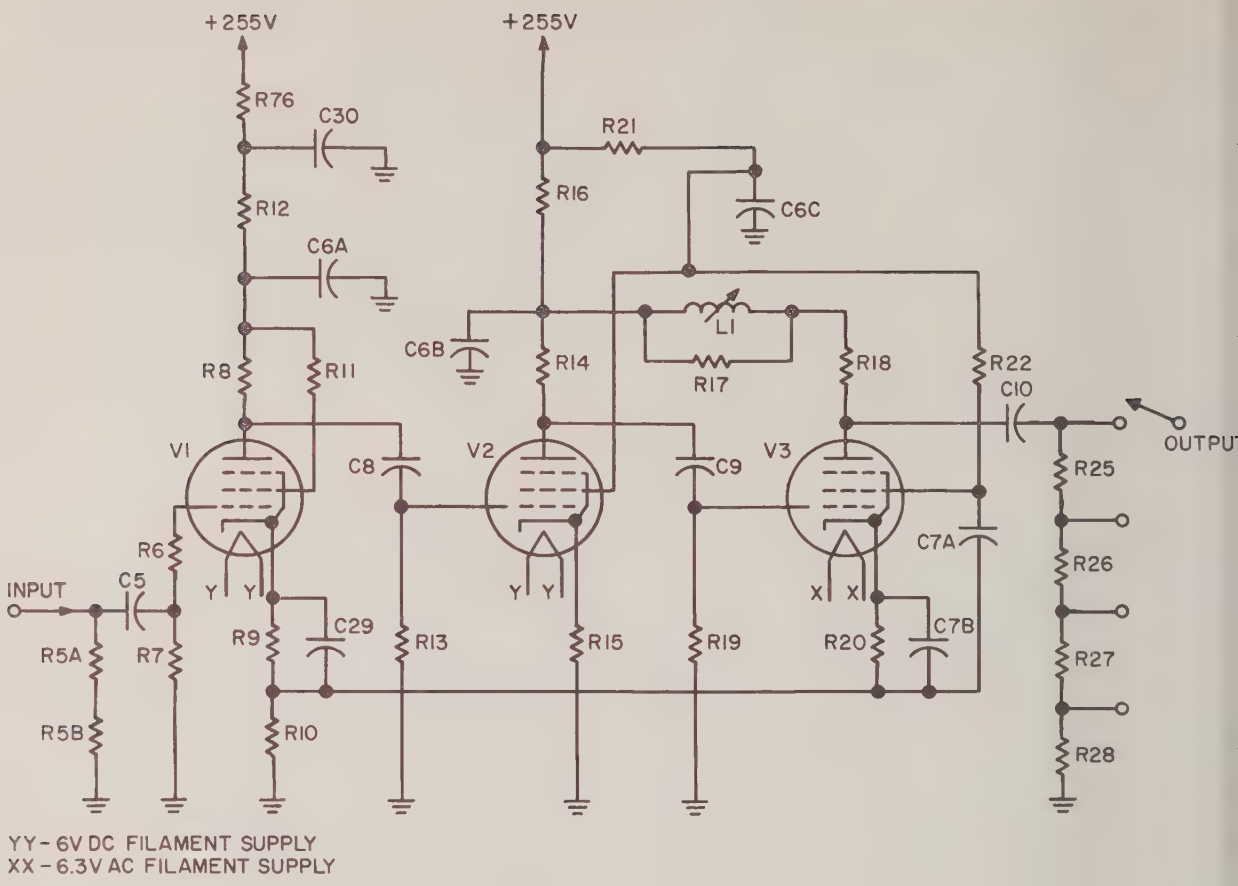


Figure 3-3. Amplifier A and Midsection Attenuator, Schematic Diagram

and decoupled by resistor R16 and a capacitor C6B. This filter and decoupling network also serves the plate circuit of peaked amplifier stage V3. The screen grid has its own decoupling and filter network, resistor R21 and capacitor C6C. The amplifier output of V2 is coupled to V3 through capacitor C9.

3-43 Peaked Amplifier Stage

3-44 Amplifier stage V3 is a class A amplifier employing cathode bias, provided by resistor R20. The stage supplies a feedback voltage to V1 through the common cathode resistor R10. The plate load of V3 consists of resistor R18 and inductor L1 in series. Consequently, a higher output voltage is obtained for higher-frequency signals. The amount of rise offsets the loss due to shunt capacities in the rest of amplifier A and maintains the flat overall response of amplifier A within the specified frequency range. The procedure for adjusting L1 to assure this response is covered in paragraphs 4-25 through 4-28. The screen grid voltage is obtained from the 255-volt regulated power supply through two filter and decoupling networks, resistor R21 and capacitor C6C (which is shared with the screen grid of V2), and capacitor C7B and resistor R22. The output is coupled through the large capacitance of C10 to the midsection attenuator.

3-45 MIDSECTION ATTENUATOR

3-46 The midsection attenuator (figure 3-3) consists of resistors R25 through R28 wired in a simple resistive voltage-divider circuit. Range switch S1 selects the proper resistor at the same time the input-attenuator circuit is selected for the range desired. In all cases, except on the lowest voltage range (320uv FULL SCALE), the signal is attenuated before being coupled to the following amplifier.

3-47 AMPLIFIER B AND OUTPUT CATHODE FOLLOWER

3-48 Amplifier B and the triode-type output cathode followers V5B and V6B (figure 3-4) provide a push-pull output to the output transformer. The transformer drives the detector and meter circuit.

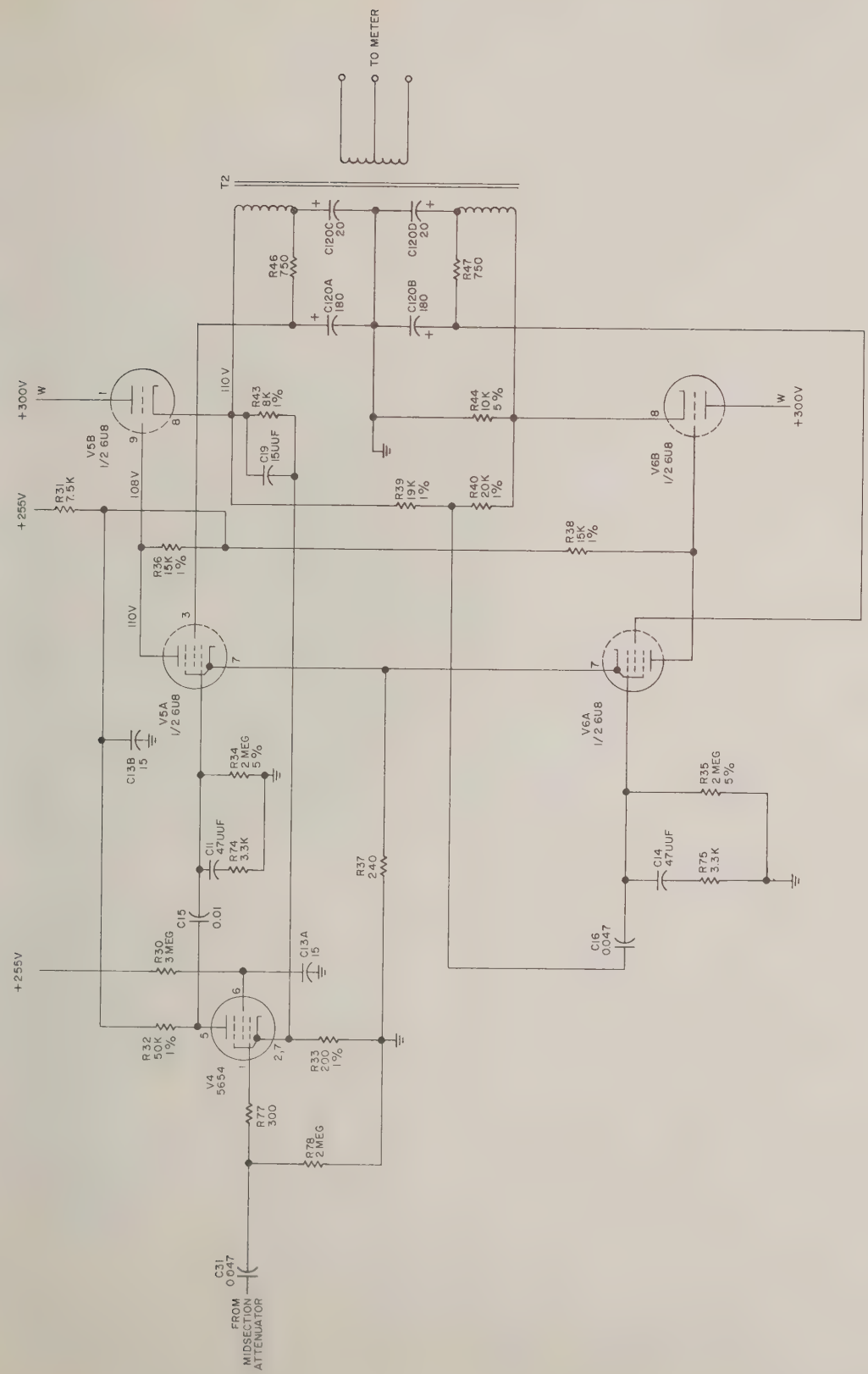


Figure 3-4. Amplifier B and Output Cathode Followers, Schematic Diagram

3-49 First Stage

3-50 The first stage is a pentode, type 5654, operating in a class A voltage-amplifier circuit. Cathode bias resistor R33 is unbypassed to introduce degeneration in the circuit. Additional feedback is provided by the cathode signal voltage of output cathode follower V5B. Plate load resistor R32 develops the output voltage, which is coupled to V5A through capacitor C15. The screen-grid voltage is obtained through resistor R30 from the 255-volt regulated power supply. Capacitor C13A filters and decouples.

3-51 Output-Amplifier and Cathode-Follower Stages

3-52 Pentode-triode V5 is used as the output stages of the amplifier. Pentode V5A is a class A voltage amplifier and triode V5B is the output cathode follower. The pentode shares a common cathode bias resistor (R37) with V6A. The output is direct-coupled to the control grid of the triode with resistor R36 serving as the plate load of V5A and the grid resistor of V5B. A high-frequency compensation network consisting of capacitor C11 and resistor R74 shunts the grid-return resistor R34 of V5A. This compensation network reduces the effects of transient noise in the amplifier circuit.

3-53 The screen-grid voltage of V5A is obtained from the cathode of the output cathode follower. The cathode voltage is filtered and maintained constant by resistor R46 and capacitors C20A and C20C. This unique method of providing screen-grid voltage is self compensating. For example, the normal voltage relationships are 108 volts for the plate of V5A and 110 volts for the screen grid. An increase in plate voltage would necessarily increase the direct-coupled control-grid voltage of V5B. Consequently, the cathode voltage of cathode follower V5B rises and since this supplies the screen-grid voltage to the V5A, the screen-grid voltage rises correspondingly. Thus, the plate and screen-grid voltage relationships in V5A are maintained unchanged. The compensation operates only for long-time changes in voltage and not for signal-voltage change due to the action of the filter. In addition, the filter decouples V5A screen grid from the cathode signal of V5B.

3-54 Phase Inverter and Output Cathode Follower

3-55 The input signal for the phase inverter V6A is obtained from a bridge circuit. The input to the bridge is the cathode voltage of the output cathode followers. The two sections of the primary of output transformer T2 constitute two legs of the bridge and resistors R39 and R40 form the other two legs. Due to the slight unbalance in resistors R39 and R40, an output voltage is obtained to drive phase inverter V6A. The phase inverter is identical to V5A except that the signal input is of opposite phase. The output cathode follower is similar to the V5B output cathode follower except for cathode bias. The cathode does not supply feedback bias, but in all other respects the circuits are identical.

3-56 Meter Rectifier and Root-Mean-Square Detector

3-57 Meter Rectifier

3-58 A full-wave rectifier consisting of diodes CR2 and CR3 produces a positive output from the secondary of voltage transformer T2 (figure 3-5). The path of the unidirectional current flow is through the 200-microampere moving-coil meter, thermistor RT1, and resistor R54. Capacitor C27 bypasses the current variations around the meter. To compensate for the effects of heating in the diodes and other circuit components, thermistor RT1 is used. A thermistor exhibits a negative temperature coefficient, i.e., as the temperature rises, the resistance of the thermistor decreases. This offsets the positive temperature coefficient exhibited by other circuit elements. The indication of rectifier and meter, as described, is not a true root-mean-square voltage. However, a unique addition of diodes and resistors gives the instrument the characteristic of indicating rms voltages for complex and sine waves.

3-59 Root-Mean-Square Detector

3-60 The circuit consisting of resistors R56 through R73 and diodes CR4 through CR11 gives a true root-mean-square indication of the voltage applied to the INPUT terminals (figure 6-1). Before the voltage to be measured is present, the resistors form eight parallel voltage dividers between ground and +87 volts. It can be seen that the voltage at the junctions of resistors and diodes differs for each junction, and that the voltage is progressively higher from the cathode of CR11 to the cathode of CR4. This sets a bias on every diode, with the cathode more positive than the anode. This bias maintains every diode in a non-conducting condition. Consequently, no current flows through the diodes, although voltage-divider current flows through the resistors. Under initial conditions, the load that the rms detector places on the meter rectifier is that of resistor R73 alone.

3-61 Assume a small voltage is applied to the INPUT terminals. The voltage output from the meter rectifier raises the cathode voltage of CR11. Since the anode of CR11 is only slightly positive (approximately 0.5 volt) due to the biasing action of resistors R64 and R72, the rectifier output is sufficient to start conduction in CR11. Thus, the load on the meter rectifier is now R72 in parallel with R73. The additional current flow is through resistor R72, CR11, meter rectifiers CR2 and CR3, transformer secondary T2, and the meter. This slight additional current increases the deflection of the meter pointer. If a still higher voltage is applied to the INPUT of the instrument, the meter rectifier output is a more positive voltage. This overcomes the bias on diode CR10, and conduction takes place through R71, CR10, and the meter rectifier circuit in addition to conduction through CR11. The meter is deflected further. The values of resistors are selected to give a current that is proportional to the square of the input voltage. The meter is calibrated in terms proportional to the square root of its current. Consequently, the root-mean-squaring operation is accomplished.

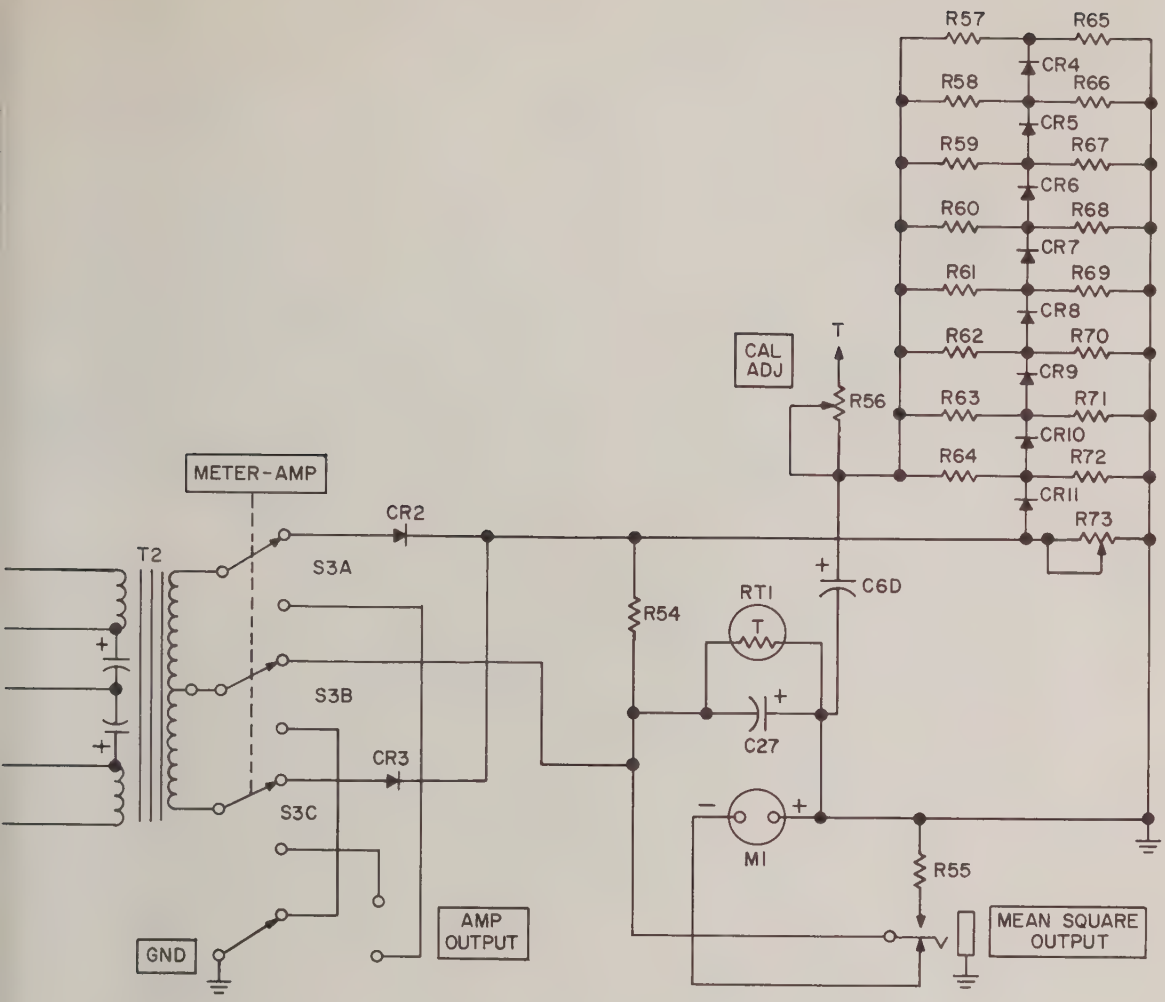


Figure 3-5. Meter Rectifier and Root-Mean-Square Detector, Schematic Diagram

3-62 Detector response corresponding to full-scale meter deflection is controlled by resistor R56 (CAL ADJ), which sets the detector-bias supply voltage. Procedure for checking this control is covered in paragraph 4-41.

3-63 Monitor Amplifier

3-64 The monitor amplifier (figure 3-6) uses a twin-triode type 12AV7 tube connected in series amplifier circuit. The input signal is taken from the cathode of V6B and applied through capacitor C23 to the top section of the amplifier. The output is coupled through capacitor C24 to the control grid of the lower section of V7. The unique feature of the cascade amplifier is the nature of the plate load of the lower section. The load consists of resistor R52 and the upper triode. The amplifier signal output is taken from the cathode of the upper triode. The monitor amplifier presents an extremely light load to the phase inverter and, therefore, does not effect phase inverter operation. The circuit is degenerative and exhibits a stable wide-range output response.

3-65 Power Supply

3-66 The instrument is delivered ready to operate on 115-volts a.c., 50 to 420 cps. It is possible to change the power-transformer strapping to permit operation on 230 volts (paragraphs 4-14 and 4-15). A type 5V4G cathode-type twin-diode tube (figure 6-1) is used in a full-wave rectifier with a capacitor-input filter network. A pi-type filter consisting of resistor R42 and capacitor C18 supplies +300-volts dc for operation of the balanced-output cathode followers. An additional filter network consisting of resistor R41 and capacitor C17 supplies voltage to a gas-tube voltage-regulator circuit that includes V8 and V9. The regulated

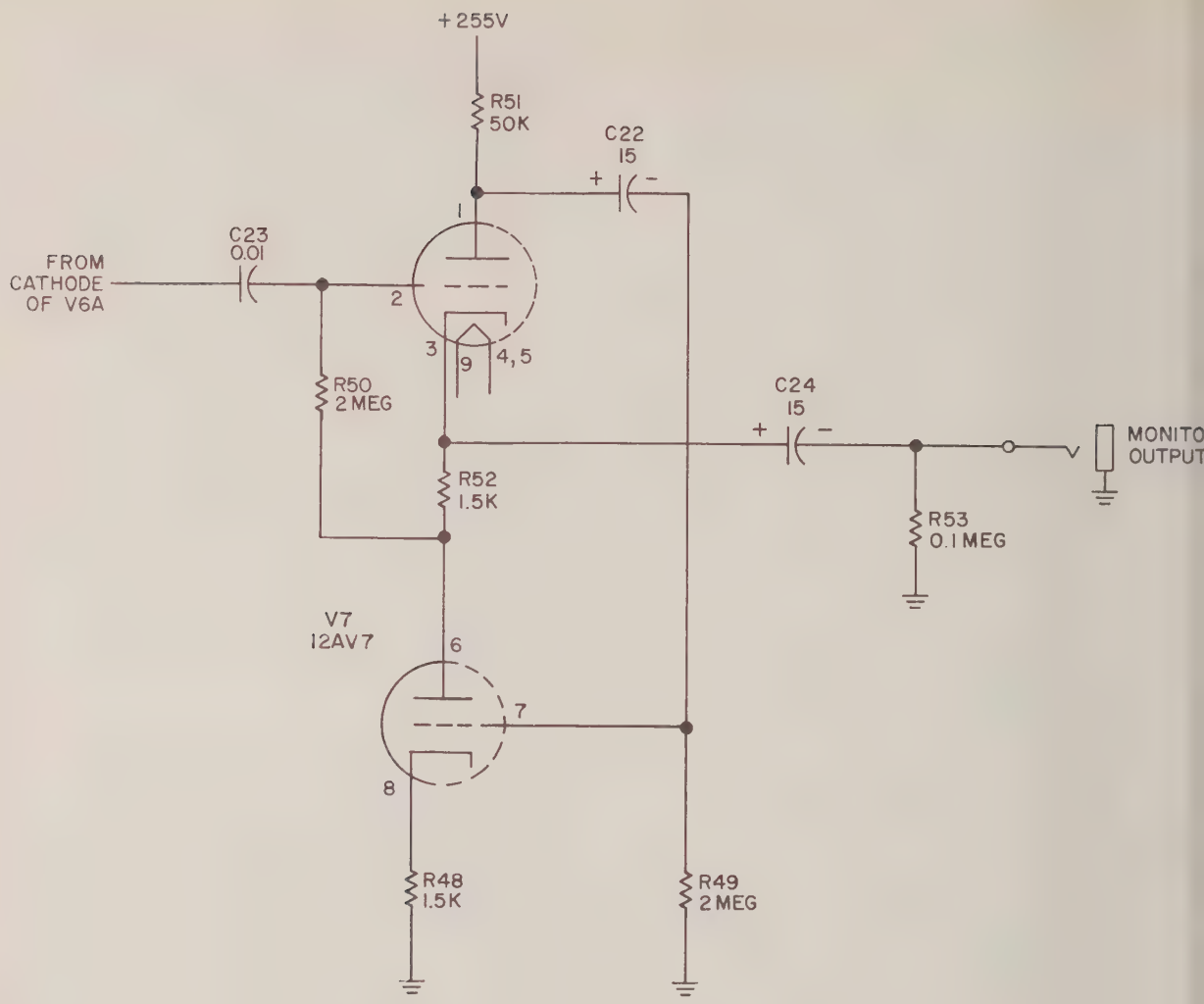


Figure 3-6. Monitor Amplifier, Schematic Diagram

output voltage is used for the amplifier tubes after further filtering and decoupling. A gas-type reference tube V10 is used to provide a regulated source of +87 volts dc to supply bias to the root-mean-square detector.

3-67 A source of d.-c. voltage for the heaters of the first two amplifier stages is provided by rectifying the voltage obtained from a separate secondary on power transformer T1. Selenium rectifiers CR1A and CR1B constitute a full-wave rectifier whose output is filtered by capacitor C21 and resistor R45.

3-68 A voltage divider consisting of resistors R23 and R24 provides approximately 75-volts dc. One side of the heater line is connected to this point to raise the heaters to a d.-c. potential of 75 volts. This reduces the possibility of heater-cathode leakage in the amplifier tubes heated off this filament line, thereby reducing the possibility of hum.

TRUE ROOT MEAN SQUARE ELECTRONIC VOLTMETER
BALLANTINE MODEL 320-S/1

SECTION IV
MAINTENANCE

4-1 PERIODIC MAINTENANCE PROCEDURES

4-2 Ballantine Model 320-S/1 True Root Mean Square Electronic Voltmeter is a valuable servicing tool. it is a precision general-purpose a.-c. vacuum-tube voltmeter with an excellent rms response. This feature makes it very useful in taking accurate noise measurements. Consequently, it is anticipated that the instrument will not be subjected to long or frequent periods of use. It is imperative, therefore, that the instrument be checked periodically to see that it is in operating condition for the time when it is required.

--WARNING--

Voltages dangerous to human life exist in this equipment. Exercise care whenever instrument is removed from case.

4-3 MONTHLY MAINTENANCE

4-4 Once a month, connect instrument to a source of power and operate it. Use the internal calibrator and check the calibration of the instrument in accordance with paragraph 2-15. In addition, a visual inspection should be performed as follows:

a. Inspect line cord for cuts, breaks, or signs of deterioration.

b. Inspect for looseness of switches, knobs, connectors and pilot-light jewel.

c. Inspect meter glass for signs of damage.

d. Inspect case for signs of paint chipping or other damage.

e. Clean case and meter face.

4-5 ANNUAL MAINTENANCE

4-6 Once each year, perform the following

a. Check calibration of instrument on all ranges with an external calibrator such as Meter Test Set AN/GSM-1B.

b. Remove tubes (figure 4-1) and test. Replace any that test weak or questionable.

c. Check signal balance at cathode of each output cathode follower. Replace tubes if balance cannot be obtained.

4-7 SERVICING PROCEDURES

4-8 REPLACEMENT OF FUSE AND PILOT LIGHT

4-9 Fuse F1 is located adjacent to the power-cord entrance to the instrument. It can be reached without removing the instrument from the case. Remove fuse cap and inspect fuse. If burned out, replace with a 1-ampere type 3AG fuse. (If the instrument is wired for 230-volt operation, a 1/2-ampere fuse is required.) A spare fuse is supplied and is stowed inside the instrument case.

4-10 A bayonet-base pilot light, type 47, can be replaced from the front without removing the instrument from its case. To replace, unscrew red plastic cap on panel; then push in and twist bulb simultaneously. A spring ejects bulb into hand. Replace with same type bulb by pushing bulb against spring and twisting to lock in place.

4-11 REMOVAL OF INSTRUMENT FROM CASE AND RETURN TO CASE

4-12 To remove instrument from case, proceed as follows:

a. Stand instrument in normal position.

b. Unscrew two large knurled thumb screws located on rear of case. Turn until front of case, attached to panel, disengages from body of case.

c. Withdraw instrument from case.

4-13 To return instrument to case, do the following:

a. Push power cord through entrance hole and pull through from rear.

b. Slide instrument as far as possible into case.

c. Engage front and rear sections of case and tighten two knurled thumb screws until equipment is firmly reassembled.

4-14 CONVERSION TO 230-VOLT OPERATION

4-15 If it is necessary to operate the instrument on 230-volts ac, rewire power transformer as follows:

a. Remove instrument from case (paragraph 4-12).

b. Unsolder black lead with a red trace from terminal 1 of power transformer T1 and resolder to terminal 3.

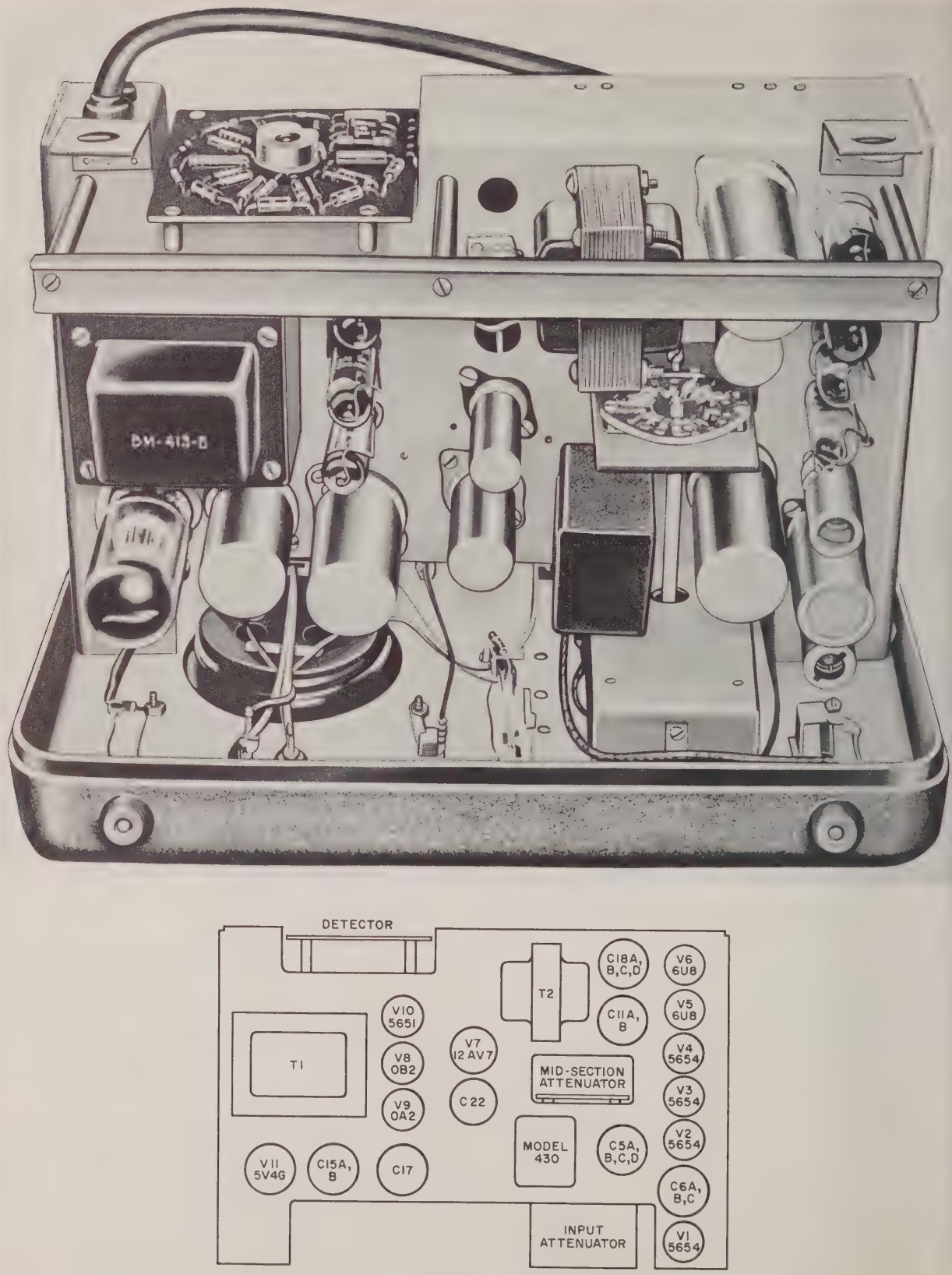


Figure 4-1. Voltmeter Chassis, Top View

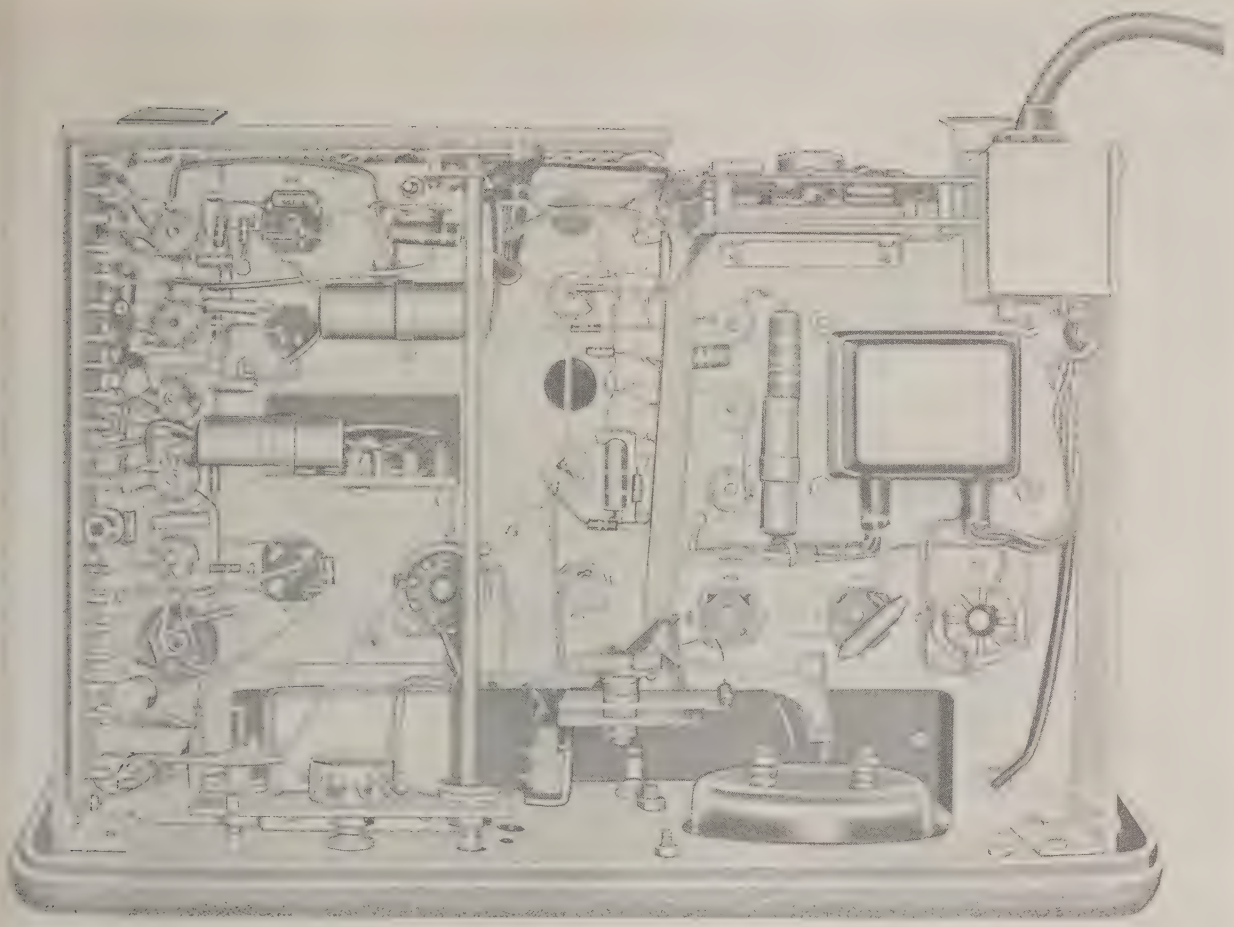


Figure 4-2. Voltmeter Chassis, Bottom View

c. Unsolder black lead with yellow trace from terminal 2 and resolder to terminal 3.

d. Mark back of instrument "230 volts" instead of "115 volts," as indicated on decal.

e. Return instrument to case (paragraph 4-13).

4-16 TROUBLE SHOOTING

4-17 Trouble shooting is covered in three phases: amplifiers, attenuators, and square-law detectors and meter. In addition, instructions are presented for the adjustment of controls.

4-18 Equipment Required

Hewlett-Packard Model 200 CD Audio Oscillator
Hewlett-Packard Model 400D AC-VTVM
Tektronix Model 310A Oscilloscope
Triplett Model KS-14510 Volt-ohm-milliameter
Hickok Model KS-15750 Tube Tester
Fiber Screwdriver, FSN 5120-288-7779

4-19 TROUBLE SHOOTING THE AMPLIFIERS

4-20 Procedure

4-21 Preliminary Inspection and Test

4-22 A visual inspection of the amplifier components should be performed first. If the defective part can be located visually, considerable time can be saved. The second step is to test all tubes and replace any found defective. If necessary, replace the premium tube, type 5654, with the commercial equivalent, 6AK5. If one or both type 6U8 tubes require replacement measure the d.-c. cathode voltages of both triode sections. The voltages should be equal. Try several tubes until the closest match is obtained. When it is necessary to replace V1, try several tubes and use the one exhibiting the lowest hum characteristic.

4-23 Signal Tracing

4-24 The amplifiers are most easily and quickly checked using a signal-tracing method. Proceed as follows:

a. Remove instrument from case.

b. Insert line cord in source of a.c.; set ON-OFF switch to ON.

c. Set range selector switch to 1V FULL SCALE position.

d. Connect Hewlett-Packard Model 200CD Oscillator to INPUT; adjust output of oscillator to 1,000 cps at 1 volt. (If instrument is operating correctly, the meter will indicate 1-volt rms. However, if the indication is inaccurate, if no indication is obtained, or if meter pointer oscillates or moves erratically, trouble is present and the procedure in 4-24 e through h should be continued.)

e. Use Hewlett-Packard Model 400D AC-VTVM to read signal voltages.

f. Read signal voltages on tubes V1 through V6, as indicated in table III. Voltages must be within ± 10%. If the proper voltage is obtained at one point and the next point exhibits an incorrect voltage, check d.-c. voltages (table IV) on the stage included between the correct and incorrect signal-voltage points.

TABLE III. SIGNAL VOLTAGES

TUBE	PIN NO.	TUBE ELEMENT	VOLTS RMS AC*
V1	1	Control Grid	0.001
V2	1	Control Grid	0.00058
V3	1	Control Grid	0.012
	5	Plate	0.43
V4	1	Control Grid	0.13
V5	2	Control Grid	0.16
	6	Plate	5.5
	8	Cathode	5.2
V6	2	Control Grid	0.13
	6	Plate	5.5
	8	Cathode	5.2

* All voltages are rms and measured with vacuum-tube voltmeter. Input voltage is 1.0-volt rms, 1,000 cps, applied to INPUT. Range selector switch on 1V FULL SCALE.

TABLE IV. VOLTAGE CHART

TUBE	VOLTS***								
	PIN 1	PIN 2	PIN 3	PIN 4	PIN 5	PIN 6	PIN 7	PIN 8	PIN 9
V1	0	4	0	5.75	60	130	4		
V2	0	2	0	5.75	100	120	2		
V3	0	1.75	75*	75*	30	100	1.75		
V4	0	3.5	*	*	110	110	3.5		
V5	300	0	110	75*	75*	108	2.75	110	108
V6	300	0	110	75*	75*	108	2.75	110	108
V7	170	**	70	75*	75*	68	0	2.5	75*
V8	255	105	-	105	255	-	105		
V9	105	0	-	0	105	-	0		
V10	87	0	-	0	87	-	0		
V11		400	-	350v a.c.	350v ac	350 v a.c.		400	
Cal Unit	0	-	75*	75*	1v a.c.	3.16 mv a.c.	-	-	

*Heater Voltage is 6.3v a.c. between heater pins.

**Loading error makes reading of little use. In such cases, an oscilloscope is more satisfactory as a signal-tracing indicator.

***All voltages are plus d.c., unless otherwise indicated.

g. When troubles are of a hum- or noise-induced nature, or are a result of unbalance or amplifier distortion, signal-voltage measurements may not localize the defective stage.

h. Substitute Tektronix Model 310A Oscilloscope for the sensitive meter and repeat signal-tracing procedure. Pay close attention to waveform observed. Measure peak-to-peak voltages at the various test points. To determine the correct peak-to-peak voltage indication, multiply the rms indication given in table III by a factor of 2.8.

4-25 Frequency-Response Adjustment of Amplifier

4-26 Equipment Required

Hewlett-Packard Model 200CD Audio Oscillator
Ballantine Model 314-S/1 VTVM
Fiber Screwdriver, FSN 5120-288-7779

4-27 Method

4-28 High-frequency compensation is adjustable in the amplifiers, low-frequency compensation is not. Inductor L1 used for high-frequency compensation is factory-adjusted and should maintain its setting. However, if it is misadjusted or if it is replaced, an approximate adjustment should be performed as follows:

a. Set instrument ON-OFF switch to ON; range selector switch to 320UV FULL SCALE: USE-CAL switch to USE; and METER-AMP switch to AMP.

b. Connect Hewlett-Packard Model 200CD Oscillator to INPUT. Adjust oscillator for an output frequency between 150,000 to 500,000 cps. Set amplitude control to give meter indication between 150 and 316uv.

c. Connect Ballantine Model 314-S/1 Vacuum Tube Voltmeter to a tee connector (figure 4-3).

d. Adjustment of inductor L1. (The inductor is located on the long terminal board at the side of the chassis adjacent to tube V3. Adjustment can be accomplished from top or bottom.)

Step	Frequency	Generator Output uv	Ballantine Model 320-S/1
1	150 kc to 500 kc	150 to 316 uv	Meter reading should be the same as on the wide band VTVM.
2	150 kc to 500 kc	Do not readjust input voltage	Adjust L1 if necessary to duplicate wide band VTVM indication.

e. If low-frequency troubles are encountered in the instrument, check coupling or cathode bypass capacitors for opens or leakage.

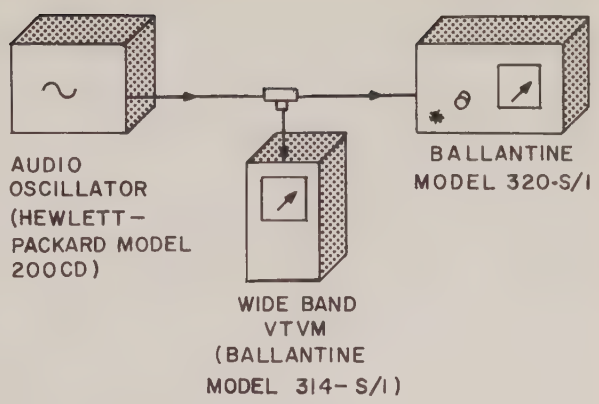


Figure 4-3. Frequency Response Adjustment Procedure

4-29 TROUBLE SHOOTING THE ATTENUATORS

4-30 The input and midsection attenuators should not require servicing during the life of the instrument since they are made entirely of stable resistors and capacitors. It is possible, however, for the input attenuator to be damaged by the inadvertent application to the input terminals of voltages in excess of 1,000 volts.

4-31 Removal of Attenuator

4-32 The following procedure is required to remove the input attenuator in order to service defective components:

a. Set range selector switch to 320UV FULL SCALE position.

b. Remove range-selector-switch knob.

c. Remove metal escutcheon plate by removing four screws.

d. Remove db dial.

e. Remove four screws holding attenuator; one screw is on each side of switch shaft and one on each side of input terminals.

f. Unsolder output connection at top of assembly.

g. Withdraw entire assembly straight out from panel.

h. If desired, unsolder ground terminal.

4-33 Frequency-Response Adjustment of Attenuators

4-34 Equipment Required

Hewlett-Packard Model 200CD Audio Oscillator
Fiber Screwdriver, FSN 5120-288-7779

4-35 Accurate factory adjustment was given to trimmer capacitors C2 and C3 to provide proper high-frequency compensation. However, if the setting of either trimmer is disturbed, or if the input to the instrument was subjected to an excessive overload, a readjustment may be necessary.

4-36 Trimmers C2 and C3 are located on the left- and right-hand sides respectively of the attenuator assembly. They can be found above the INPUT terminals. To expose trimmers, do the following:

a. Remove range-selector-switch knob.

b. Remove metal escutcheon plate.

--NOTE--

Do not remove db dial.

4-37 Adjust Capacitor C3 as follows:

a. Set range selector switch to 1V FULL SCALE or any higher range; USE-CAL switch to USE; ON-OFF switch to ON.

b. Connect Hewlett-Packard Model 200CD Oscillator to INPUT. Adjust output to any frequency between 150,000 to 500,000 cps. Set amplitude to produce some indication on meter.

c. With fiber screwdriver, adjust capacitors C2 and C3 for a minimum indication on meter.

4-38 Adjust capacitor C2 as follows:

a. Change range selector switch to either 32, 100, or 320MV FULL SCALE.

b. Do not change frequency output of sine-wave generator. Readjust amplitude control, if necessary, to give some meter deflection.

c. With fiber screwdriver, adjust capacitor C2 for minimum indication on meter.

--NOTE--

An adjustment of capacitor C3 always requires an adjustment of capacitor C2, but not vice versa.

4-39 TROUBLE SHOOTING SQUARE-LAW DETECTOR AND METER

4-40 Before trouble shooting the square-law detector and meter circuit, it must first be ascertained that the amplifier is functioning correctly. Check amplifier for correct operation as follows:

a. Set ON-OFF switch to ON; USE-CAL switch to CAL; METER-AMP switch to AMP.

b. Measure signal voltage from each side of output transformer to ground. If a voltage of 5-volts rms is obtained, the amplifier is operating correctly. Proceed to trouble shoot the square-law detector and meter. If reading is not 5 volts, trouble exists in the amplifier.

4-41 The Procedure for Trouble Shooting the Square-law Detector and Meter is as Follows:

a. Check d.-c. voltage on both outer terminals of CAL ADJ control R56. It should be 87 volts on the supply side and approximately 64 volts on the other.

b. Set METER-AMP switch to METER. Leave USE-CAL switch at CAL position.

c. Insert plug and cord into MEAN SQUARE OUT jack. Connect d.-c. probe of Hewlett-Packard Model 410B Vacuum Tube Voltmeter to other end of cord. If an output is obtained, check the meter or by-pass capacitor C27. Replace either one found defective. On the other hand if no output is obtained, proceed to step d.

d. Check crystal diodes CR2 and CR3. Unsolder one end of the diode, let cool, and check with ohmmeter section of the VTVM for back and forward resistance. The back resistance must exceed 1,000,000 ohms and the forward resistance must be in the order of several hundred ohms. Replace if resistance varies beyond these limits.

e. To check crystal diodes CR4 through CR11 proceed in the following manner:

1. Short circuit the input terminals to the Model 320-S1 with a wire strap.

2. Make D.C. bias voltage measurements by inserting a D.C. VTVM between chassis (-) and the points listed; compare this value with the limits shown.

CRYSTAL	VOLTS
CR4 Cathode	11.0 to 13.5
CR5 Cathode	6.7 to 7.4
CR6 Cathode	4.4 to 5.1
CR7 Cathode	3.0 to 3.6
CR8 Cathode	2.0 to 2.4
CR9 Cathode	1.4 to 1.7
CR10 Cathode	0.9 to 1.1
CR11 Cathode	0.5 to 0.7
CR11 Anode	0 to 0.3

3. Perform a forward-to-backward resistance check of the crystal diodes. Crystal diodes with a high forward resistance or completely open can readily be detected by operating the instrument out of its case and connecting a similar type diode in parallel with one that appears defective.

--CAUTION--

Care must be exercised in soldering crystal diodes. Heat can ruin them. Use a long nose pliers as a heat shunt between soldering iron and diode body.

4-42 TROUBLE SHOOTING THE POWER SUPPLY

4-43 If no d.-c. voltages are present in the amplifier or detector circuits, the power supply should be checked. Rectifier tube 5V4G should be replaced and, if that fails to restore normal voltages, the electrolytic capacitors used for filtering and decoupling should be checked. Measurement of resistance to ground should detect the defective capacitor. It may be necessary, in the case of a shorted capacitor, to unsolder leads and test each capacitor section individually.

4-44 If excessive hum is encountered, an oscilloscope should be used to measure hum voltages in the d.-c. power supply and in the d.-c. heater supply. The permissible hum voltages in peak-to-peak indications is given in Table V.

TABLE V. HUM VOLTAGES

TEST POINT	VOLTAGE (Peak-to-Peak AC)
V11, pin 8	30-40
Junction R42 and C18A	0.3
V8, pin 5	2
Junction R45 and C21	0.4
Cathode CR1A or CR1B	2-3

4-45 If the instrument exhibits unduly high susceptibility to transient signals and line-voltage changes, replace the OA2 and OB2 regulator tubes.

4-46 ELECTRICAL OVERLAP ADJUSTMENT

4-47 If, during meter calibration (paragraph 2-15), it is found that the meter adjust screw is inadequate to make the bottom-meter-scale adjustment, then the electrical overlap adjustment R73 must be set. Proceed as follows:

a. Insert a plug and cord in the MEAN SQUARE OUT jack. Connect Hewlett-Packard VTVM, set on -dc function, to other end of cord.

b. Perform meter calibration in accordance with procedure of paragraph 2-15.

c. Adjust CAL ADJ control R73 for exactly -0.2 volt output. CAL ADJ control can be reached through a ventilation hole on rear of case.

d. Set range selector switch to next higher range.

e. Readjust CAL ADJ control R73 for exactly -.02 volt output.

f. Repeat steps c through e several times.

g. Remove VTVM and plug.

h. Perform calibration procedure (paragraph 2-15) using instrument meter as indicator of calibration.

4-48 TROUBLE IN CALIBRATOR UNIT MODEL 430

4-49 Servicing the calibrator is not recommended. If it is known to be defective, it should be removed from the instrument by unscrewing the two screws holding the mounting tabs at the base of the unit to the chassis. The unit can then be pulled out.

--WARNING--

Use extreme care in handling the calibrator unit. Pack carefully, if it is to be shipped.

4-50 PREPARATION FOR RESHIPMENT

4-51 If it is necessary to reship the unit, or return it to the manufacturer for extensive repairs, at least four inches of padding material should be used in packing. Surround the instrument or any separate parts with the padding.

TRUE ROOT MEAN SQUARE ELECTRONIC VOLTMETER
BALLANTINE MODEL 320-S/1

SECTION V
PARTS LIST

5-1 GENERAL

5-2 A list of replaceable parts is included in this section. The circuit symbols refer to the schematic diagram (figure 6-1) of this manual. The Ballantine Part number or the manufacturer's type number may be used in ordering replacement parts. The manufacturer of each part is designated by a coded abbreviation. The meaning of the abbreviation is given in the list of manufacturers following the listing of parts.

5-3 The instrument is a precision device and care must be exercised in selecting replacement parts.

CAPACITORS

CIRCUIT SYMBOL	BALLANTINE PART NO.	CAPACITY AND VOLTAGE	MFG. OR JAN. TYPE NO.	MFG. CODE
C1	2135	0.033 uf, 1,000 v	621S	G
C2A	2429	7-45 uuf	TS 2A-N500	E
C2B	2228	50 uuf, 500 v	CM-15	A
C3A	2433	0.75-1.5 uuf	3MB11-160-203	J
C3B	2235	2.0 uuf, 1,000 v	CM-15	A
C4	2233	3,300 uuf	1R5D33	CD
C5	2134	0.047 uf, 200 v	620S	G
C6A	2024	40 uf, 300 v	DFP	S
C6B	2024	40 uf, 300 v	DFP	S
C6C	2024	40 uf, 300 v	DFP	S
C6D	2024	20 uf, 150 v	DFP	S
C7A	2025	10 uf, 300 v	DFP	S
C7B	2025	150 uf, 6 v	DFP	S
C8	2137	0.22 uf, 200 v	621S	G
C9	2136	0.01 uf, 400 v	621S	G
C10	2067	12 uf, 250 v	BR-1225	CD
C11	2530	47 uuf, 500 v	GPIK	E
C12	2145	0.01 uf, 400 v	109P10304	S
C13A	2004	15 uf, 300 v	DFP	S
C13B	2004	15 uf, 300 v	DFP	S
C14	2530	47 uuf, 500 v	GPIK	E
C15	2136	0.01 uf, 400 v	621S	G
C16	2134	0.047 uf, 200 v	620S	G
C17	2110	0.047 uf, 400 v	109P47304	S
C18A	2026	30 uf, 500 v	DFP	S
C18B	2026	10 uf, 500 v	DFP	S

CAPACITORS (cont)

CIRCUIT SYMBOL	BALLANTINE PART NO.	CAPACITY AND VOLTAGE	MFG. OR JAN. TYPE NO.	MFG. CODE
C19	2532	15 uf, 500 v	GPIK	E
C20A	2033	180 uf, 150 v	DFP	S
C20B	2033	180 uf, 150 v	DFP	S
C20C	2033	20 uf, 150 v	DFP	S
C20D	2033	20 uf, 150 v	DFP	S
C21	2020	3,000 uf, 10 v	DFP	S
C22	2110	0.047 uf, 400 v	109P47304	S
C23	2145	0.01 uf, 400 v	109P10304	S
C24	2002	15 uf, 300 v	DFP	S
C25	2164	0.01 uf, 600 v	102P15	S
C26	2164	0.01 uf, 600 v	102P15	S
C27	2060	100 uf, 50 v	BRH-501	CD
C28	2506	4.7 uuf,	GA-6	ST
C29	2076	5 uf,	BBR-5-6	CD
C30	2010	40 uf, 300 v	DFP	S
C31	2109	0.047 uf, 200 v	67P47302	S

RESISTORS, CARBON COMPOSITION

CIRCUIT SYMBOL	BALLANTINE PART NO.	RESISTANCE (Ohms)	TOLERANCE	MFG. OR JAN. TYPE NO.	MFG. CODE
R1	1463	10 Megohms	1%	DCF	IRC
R2	1384	338,000	1%	CA-H-1/2	P
R3	1650	9,700	1%	N20	C
R4	1651	316	1%	N20	C
R5A	1087	22 Megohms	5%	EB	AB
R5B	1087	22 Megohms	5%	EB	AB
R6	1090	510	10%	EB	AB
R7	1470	13 Megohms	1%	CP-1	W
R8	1554	50,000	1%	L-1/2	ELEC
R9	1054	2,000	5%	EB	AB
R10	1369	20	1%	CP-1/2	W
R11	1090	510	10%	EB	AB
R12	1040	20,000	5%	EB	AB
R13	1007	2 Megohms	5%	EB	AB

RESISTORS, CARBON COMPOSITION (cont)

CIRCUIT SYMBOL	BALLANTINE PART NO.	RESISTANCE (Ohms)	TOLERANCE	MFG. OR JAN. TYPE NO.	MFG. CODE
R14	1321	15,000	1%	CP-1/2	W
R15	1063	300	5%	EB	AB
R16	1266	6,800	5%	GB	AB
R17	1044	10,000	5%	EB	AB
R18	1321	15,000	1%	CP-1/2	W
R19	1010	1 Megohm	5%	EB	AB
R20	1063	300	5%	EB	AB
R21	1032	47,000	5%	EB	AB
R22	1042	15,000	5%	EB	AB
R23	1021	270,000	10%	EB	AB
R24	1016	470,000	10%	EB	AB
R25	1321	15,000	1%	CP-1/2	W
R26	1658	4,740	1%	N20	C
R27	1657	1,500	1%	N20	C
R28	1655	694	1%	N20	C
R29	1253	30,000	5%	GB	AB
R30	1020	300,000	5%	EB	AB
R31	1267	7,500	5%	GB	AB
R32	1311	50,000	1%	CP-1/2	W
R33	1715	200	1%	RS-2	D
R34	1007	2 Megohms	5%	EB	AB
R35	1007	2 Megohms	5%	EB	AB
R36	1321	15,000	1%	CP-1/2	W
R37	1082	240	5%	EB	AB
R38	1321	15,000	1%	CP-1/2	W
R39	1365	19,000	1%	CP-1/2	W
R40	1320	20,000	1%	CP-1/2	W
R41	1721	3,000	5%	10KT	S
R42	1719	4,000	5%	27E	S
R43	1714	8,000	1%	RS-5	D
R44	1203	10,000	5%	HB	AB
R45	1582	2.4		BW-1/2	IRC
R46	1059	750	5%	EB	AD
R47	1059	750	5%	EB	AB
R48	1086	1,500	5%	EB	AB
R49	1007	2 Megohms	5%	EB	AB
R50	1007	2 Megohms	5%	EB	AB
R51	1311	50,000	1%	CP-1/2	W
R52	1086	1,500	5%	EB	AB
R53	1026	100,000	5%	EB	AB

RESISTORS. CARBON COMPOSITION (cont)

CIRCUIT SYMBOL	BALLANTINE PART NO.	RESISTANCE (Ohms)	TOLERANCE	MFG. OR JAN. TYPE NO.	MFG. CODE
R54	1311	50,000	1%	CP-1/2	W
R55	1338	1,000	1%	CP-1/2	W
R57	1399	32,400	1%	DC-1/2	ELEC
R58	1396	125,000	1%	DC-1/2	ELEC
R59	1395	304,000	1%	DC-1/2	ELEC
R60	1394	685,000	1%	DC-1/2	ELEC
R61	1374	1.55 Megohms	1%	DC-1/2	ELEC
R62	1375	3.48 Megohms	1%	DC-1/2	ELEC
R63	1405	7.23 Megohms	1%	DC-1/2	ELEC
R64	1404	10.4 Megohms	1%	DC-1/2	ELEC
R65	1403	6,000	1%	DC-1/2	ELEC
R66	1402	13,200	1%	DC-1/2	ELEC
R67	1401	20,700	1%	DC-1/2	ELEC
R68	1400	30,600	1%	DC-1/2	ELEC
R69	1398	45,600	1%	DC-1/2	ELEC
R70	1397	67,500	1%	DC-1/2	ELEC
R71	1382	94,400	1%	DC-1/2	ELEC
R72	1383	78,500	1%	DC-1/2	ELEC
R74	1089	3,300	5%	EB	AB
R75	1089	3,300	5%	EB	AB
R76	1034	39,000	5%	EB	AB
R77	1063	300	5%	EB	AB
R78	1007	2 Megohms	5%	EB	AB
R101A	1624	2,000	1%	24J	SH
R101B	1624	156	1%	24J	SH
R104A	1625	20,000	0.5%	24J	SH
R104B	1625	63.25	0.5%	24J	SH
R105	1584	56	10%	BW-1/2	IRC

RESISTORS, ADJUSTABLE

CIRCUIT SYMBOL	BALLANTINE PART NO.	RESISTANCE (Ohms)	MFG. OR JAN. TYPE NO.	MFG. CODE
R56	1819	10,000	43-10K	CL
R73	1911	500,000	Q	IRC
R102	1827	500	WC807	WIRT
R103	1821	4,000	A	M

TUBES, ELECTRON AND RECTIFIER

CIRCUIT SYMBOL	BALLANTINE PART NO.	TYPE	MFG. OR JAN. TYPE NO.	MFG. CODE
V1,2,3,4	3126	Tube Electron, Type 5654		RCA or GE
V5, V6	3121	Tube Electron, Type 6U8		RCA or T
V7	3127	Tube Electron, Type 12AV7		RCA or GE
V8	3106	Tube Electron, Type 0A2		RCA
V9	3128	Tube Electron, Type 0B2		RCA
V10	3117	Tube Electron, Type 5651		RAY
V11	3148	Tube Electron, Type 5V4G		RCA
CR1A	3077	Rectifier, Selenium	Q1C1S1F	RR
CR1B	3077	Rectifier, Selenium	Q1C1S1F	RR
CR2, 3	5551	Diodes, Crystal	1N38A	AM
CR47 thru CR11	3119	Diodes, Crystal	1N54	B
RT-1	1583	Thermistor	43R1	VIC
RT-101	3131	Lamp, Resistor		B

OTHER COMPONENTS

CIRCUIT SYMBOL	BALLANTINE PART NO.	DESCRIPTION	MFG. OR JAN. TYPE NO.	MFG. CODE
L1	3004	Coil, adjustable, 0.7-3.0 millihenry	3004	B
T1	3037	Transformer, power	3057	B
T2	3038	Transformer, output	3038	B
T101	3039	Transformer, power	3039	B
F1	3407	Fuse, 1.0 ampere	3AG	L
I1	3451	Lamp, pilot	47	GE
M1	3164	Meter	3164	B
S1	3231	Switch, range selector	L	B
S2	3232	Switch, CAL-USE	F	B
S3	3233	Switch, Meter-Amp	F	B
S4	3234	Switch, ON-OFF	20994 LH	AH

LIST OF MANUFACTURERS

CODE USED IN PARTS LIST	MANUFACTURER'S NAME	ADDRESS
A	Arco Electronics	
AB	Allen-Bradley	
AH	Arrow, Hart and Hegemann	
AM	Amprex	
B	Ballantine Laboratories, Inc.	Boonton, N.J.
C	Corning Glass	Corning, N.Y.
CD	Cornell-Dubilier Electric	
CL	Clarostat	
D	Dale	
E	Erie Resistor	
ELEC	Electra of Col	
G	Good-All	
GE	General Electric Company	
IRC	International Resistance Co.	Phil., Pa.
L	Littlefuse	
M	Muter	
P	Phaostron	
RAY	Raytheon Mfg. Co.	
RCA	Radio Corporation of America	
RR	Radio Receptor	
S	Sprague Electric	
SH	Shallcross	
ST	Stackpole Carbon	
T	Tung-Sol	
VIC	Victory Engineering	
W	Wilkor	
WIRT	Wirt Resistor	

TRUE ROOT MEAN SQUARE ELECTRONIC VOLTMETER
BALLANTINE MODEL 320-S/1

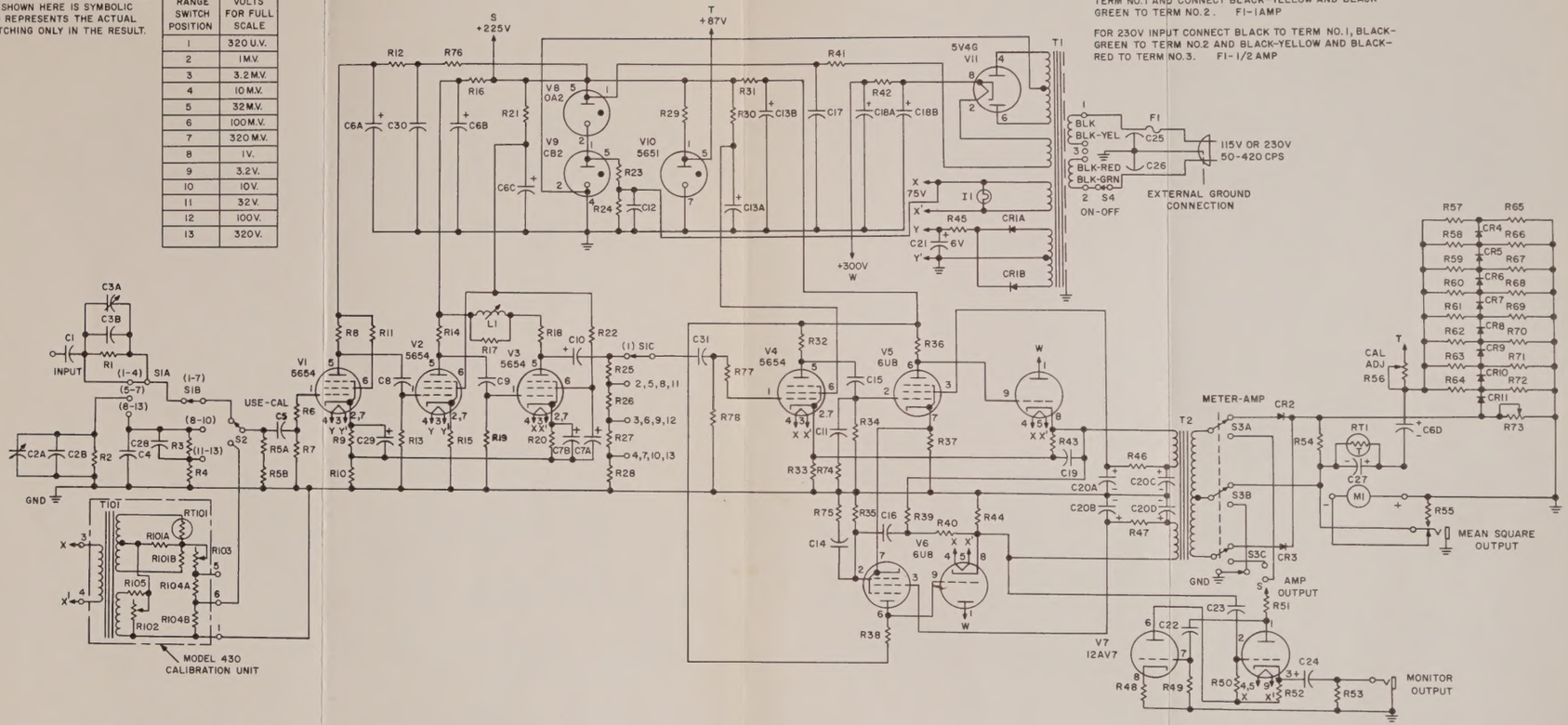
SECTION VI
DRAWINGS

6-1 GENERAL

6-2 A schematic diagram of the voltmeter is shown in this section.

THE SYSTEM OF RANGE SWITCHING (SI) SHOWN HERE IS SYMBOLIC AND REPRESENTS THE ACTUAL SWITCHING ONLY IN THE RESULT.

RANGE SWITCH POSITION	VOLTS FOR FULL SCALE
1	320 U.V.
2	1 M.V.
3	3.2 M.V.
4	10 M.V.
5	32 M.V.
6	100 M.V.
7	320 M.V.
8	1 V.
9	3.2 V.
10	10 V.
11	32 V.
12	100 V.
13	320 V.


FOR 115V INPUT CONNECT BLACK AND BLACK-RED TO TERM NO. 1 AND CONNECT BLACK-YELLOW AND BLACK-GREEN TO TERM NO. 2. FI-1 AMP
FOR 230V INPUT CONNECT BLACK TO TERM NO. 1, BLACK-GREEN TO TERM NO. 2 AND BLACK-YELLOW AND BLACK-RED TO TERM NO. 3. FI-1/2 AMP
115V OR 230V 50-420 CPS
EXTERNAL GROUND CONNECTION
ON-OFF
INPUT
USE-CAL
MODEL 430 CALIBRATION UNIT
METER-AMP
MEAN SQUARE OUTPUT
AMP OUTPUT
MONITOR OUTPUT
CAL ADJ
+225V
+87V
+300V
GND

REVISED MAY 1958

Figure 6-1. Ballantine Model 320-S/1 True Root Mean Square Electronic Voltmeter, Schematic Diagram

MP MASTER
MA34780